STRATEGY FOR UTILIZATION

REPORT OF THE
INTERNATIONAL POTATO CENTER'S
PLANNING CONFERENCE ON UTILIZATION
OF GENETIC RESOURCES

INTERNATIONAL POTATO CENTRE INTERNACIONAL DE LA PAPA

LIMA PERU

INTERNATIONAL POTATO CENTER

REPORT OF THE PLANNING CONFERENCE ON UTILIZATION OF THE GENETIC RESOURCES OF THE POTATO

Held at CIP - Lima, Peru

April 15-19, 1974

INTERNATIONAL PLANNING CONFERENCE ON THE UTILIZATION OF THE GENETIC RESOURCES OF THE POTATO

At the request of Dr. Richard L. Sawyer, Director General of the International Potato Center, a Planning Conference was held to establish priorities and recommend specific programmes for the utilization of the wealth of genetic resources of the potato becoming available at CIP.

The truly International scope of the Conference is apparent in the following list of participants recognized as experts in breeding potatoes in nine countries of the world.

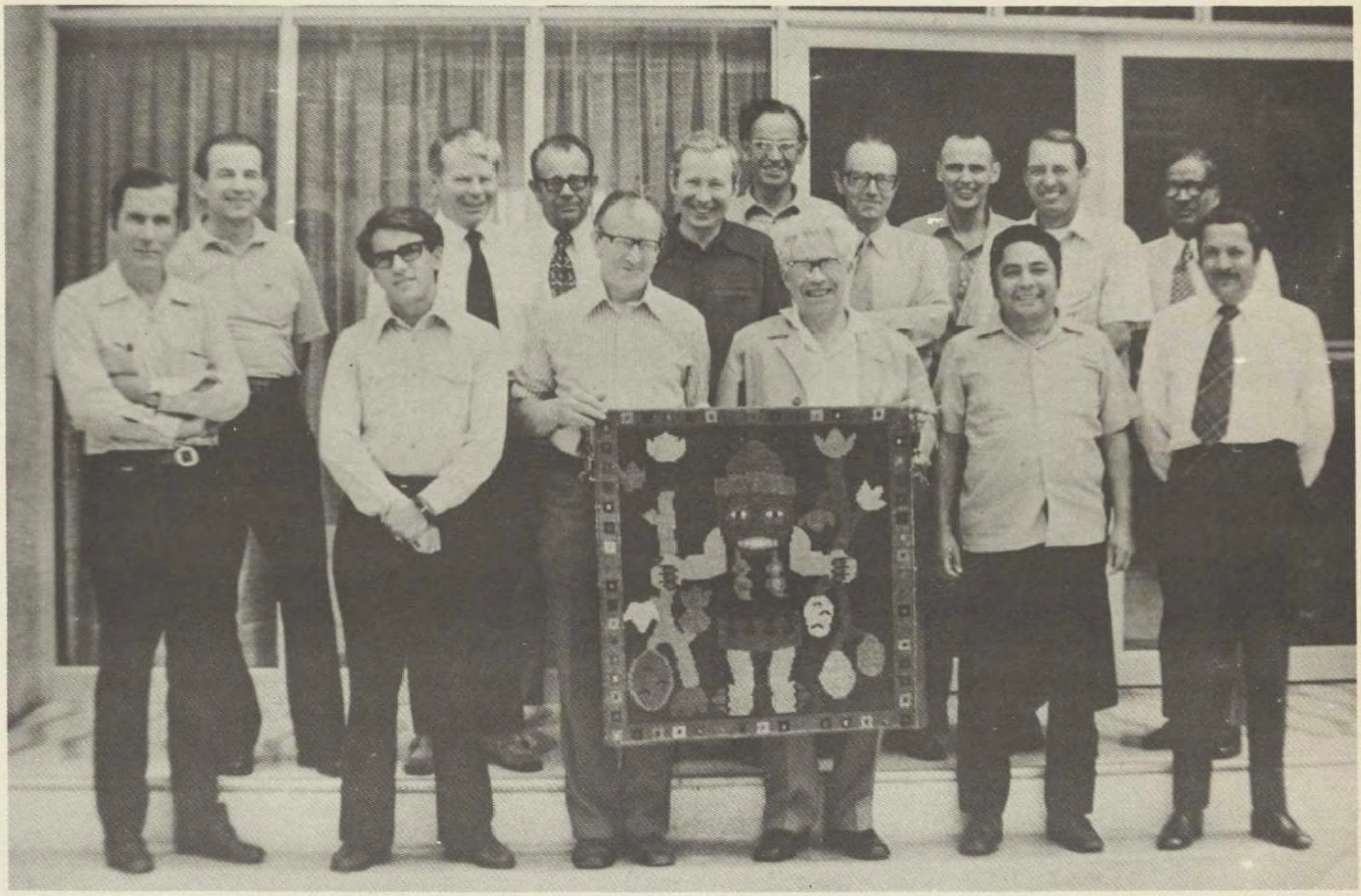
PARTICIPANTS

Dr. H. W. Howard (Chairman)	Plant Breeding Institute Cambridge CB2 2LQ, ENGLAND.
Dr. Frank Haynes	North Carolina State University Dept. of Horticultural Science P. O. Box 5216 Raleigh, North Carolina 27607 U. S. A.
Dr. John G. Th. Hermsen	Institute of Plant Breeding, Agricultural University 166, Lawickse Allee, Wageningen, THE NETHERLANDS.
Dr. Børge Jacobsen	Director Potato Breeding Institute, DK-7184 Vandel, DENMARK.
Dr. J. Jakubiec	Warszawa 02-975, Nowoursynowska 166, POLAND.
Dr. Hari Kishore	Head, Division of Genetics Central Potato Research Institute, Simla - 1, H. P. INDIA
Dr. Américo O. Mendiburu	EERA Balcarce, C. C. 276 Balcarce (Prov. de Bs. As.). ARGENTINA.

Dr. Robert L. Plaisted	Head, Dept. of Plant Breeding & Biometry, 252 Emerson Hall, Cornell University, Ithaca, New York 14850, U. S. A.
Dr. Donald A. Young	Program Manager, Potato Research Agriculture Canada Research Station, Fredericton, New Brunswick, CANADA.
Dr. Fermín de la Puente	Jefe del Departamento de Papa Programa Nacional de Papa Ministerio de Agricultura La Molina, Lima PERU.

The following members of CIP staff also attended the Planning Conference:

Dr. P. R. Rowe	Head, Dept. of Breeding & Genetics
Dr. N. Estrada	Plant Breeder
Mr. K. Proudfoot	Plant Breeder (Visiting scientist, Canada Department of Agriculture)
Mr. M. Jackson	Taxonomist
Ing. C. Ochoa, M.S.	Head, Department of Taxonomy
Dr. O. T. Page	Director of Research



Front row, left to right: Drs. Estrada, Mendiburu, Howard, Jacobsen, de la Puente and Ochoa.

Back row: Drs. Jakubiec, Page, Haynes, Young, Proudfoot, Hermesen, Plaisted, Rowe and Kishore.

C O N T E N T S

1. SUMMARY OF RECOMMENDATIONS

PRIORITY I

1. Resistance to *Pseudomonas solanacearum* and *Phytophthora infestans*.
2. Resistance of tubers to *Phytophthora infestans*.
3. Adaptation to new potato growing regions.
4. Resistance to virus "Y".
5. Conduct wide search for leaf roll resistance.
6. Resistance to cyst and root-knot nematodes.
7. Selection of frost resistant *S.* x *juzepczukii* and *S. curtilobum*.
8. Use of meristem culture to conserve genetic resources.
9. Evaluate and maintain selected clones at all ploidy levels.
10. Improve quality and maintain high production of protein.

PRIORITY II

1. Frost resistance studies in *S. ajanhuiri*, *stenotomum* and *phureja*.
2. Resistance to races of *Synchitrium endobioticum*.
3. Utilization of further sources of resistance to *P. infestans*.
4. Examination of breeding procedures specific to *Solanum* species.
5. Documentation of collections at other centers.

PRIORITY III

1. Breeding at 2 _x_ level for use in producing 4 _x_ hybrids.
2. Need for research on physiological factors in Tuberosum x Andigena influencing tuber initiation and growth.
3. Use of botanical seed to produce crops on farm scale or as substitute for certified seed.
4. Wild species - maintain as botanical seed.
5. Establishment of a data handling center to collate CIP data.
6. Screening of further lines to provide a broader genetic basis of resistance to _P. solanacearum._
7. Resistance to a spectrum of diseases and pests that are identified.

CENTRO INTERNACIONAL DE LA PAPA

INTERNATIONAL PLANNING CONFERENCE ON THE UTILIZATION OF GENETIC RESOURCES OF THE POTATO

II. AGENDA

Monday, April 15

9:00	Introduction of Participants
	Overview of the Objectives of the Planning Conference and of the Center. Dr. R. L. Sawyer, Director General
9:30	I Current Status of CIP Germ Plasm Collection.
	II Priorities and Future Goals of the Breeding and Genetics Programs. Dr. P. R. Rowe, Head, Department of Breeding and Genetics
10:30	Use of the Cultivated Diploids
	1. Useful Characteristics 2. Strategy for Utilization Dr. F.L. Haynes, North Carolina State University, U.S.A.
12:00	Lunch at La Molina

Monday afternoon

1:00	Discussions and Preliminary Recommendations on the Use of Cultivated Diploids.

3:00	Coffee
3:15	Use of the Cultivated Triploids and Pentaploids. 1. Useful characteristics 2. Strategy for Utilization Dr. F. de la Puente, Ministerio de Agricultura, Peru.
3:45-4:30	Discussion and Preliminary Recommendations on the Use of Cultivated Triploids and Pentaploids.

<u>Tuesday, April 16</u>

9:00	Use of the Cultivated Tetraploids - Andigena 1. Useful characteristics 2. Strategy for Utilization Dr. R.L. Plaisted, Cornell University, U.S.A.
10:15	Coffee
10:30	Discussion and Preliminary Recommendations on the Use of Cultivated Tetraploids - Andigena
12:15	Lunch at La Molina

<u>Tuesday Afternoon</u>

1:00	Use of the Cultivated Tetraploids - Tuberosum 1. Useful characteristics 2. Strategy for Utilization Dr. D. A. Young, Agriculture Canada
3:00	Coffee
3:15-4:30	Discussion and Preliminary Recommendations on the Use of Cultivated Tetraploids - Tuberosum

Wednesday, April 17

9:00	Use of Non-Cultivated Potato Species 1. Useful characteristics 2. Strategy for Utilization Dr. J.G. Th. Hermsen - Institute of Plant Breeding, The Netherlands.
10:15	Coffee
10:30	Discussion and Preliminary Recommendations on the Use of Non-Cultivated Potato Species.
12:15	Lunch at La Molina

Wednesday Afternoon

1:00	General Discussion on the Conservation of Potato Germ Plasm for Future Use. 1. Clonal Propagation 2. Bulk Seed Conservation 3. In vitro Techniques
3:15	Coffee
3:15-4:30	Continuing discussion

Thursday, April 18

9:00-4:30	Committee to Summarize Discussion and to Prepare Final Recommendations Dr. H. W. Howard Dr. A. O. Mendiburu Dr. D. A. Young Dr. P. R. Rowe Dr. O. T. Page

12:00	Other Participants Tour of CIP Facilities at La Molina
12:30	Lunch at La Molina

Thursday Afternoon

1:15	Other Participants Free for Discussion with CIP staff

Friday, April 19

9:00	Discussion of Final Recommendations and Assignment of Research Priorities.
12:00	Lunch at La Molina

III. INTRODUCTION

It is estimated that less than one percent of the genetic variability of *Solanum* has been utilized in the development of existing varieties of potatoes. Making wider use of genetic materials, and especially prospecting the germ plasm for multigenic field resistance to pest and diseases, can make enormously valuable contributions toward solving many problems in potato production.

The successful transfer of the potato from tropical to temperate latitudes, and later to tropical regions of Africa and Asia, has been due to the selection of clones adapted to the long days of a temperate growing season or the selection of day-length insensitive clones. From eons of natural selection in cool Andean habitats, the genus *Solanum* was also generally well adapted to grow in the relatively short frost-free season of northern regions. This wide adaptability to temperature and day-length, combined with its outstanding nutritive and yield qualities, has made the potato the fourth most widely cultivated crop of mankind.

In keeping with the philosophy of the Outreach program, the basic goal of CIP is to raise the productivity of potatoes in countries of the developing world where need and opportunity are greatest. This implies an expanded and more efficient use of the essentially untapped genetic capacity of the potato. To this end expert opinion was sought to plan how to most effectively utilize the spectrum of genetic resources available at the diploid to pentaploid levels.

The present report is based on papers summarized by opening speakers at six sessions and on a position paper prepared and circulated prior to the Planning Conference. An attempt has been made to incorporate important points raised during discussion and to summarize recommendations with suggested program priorities and expected duration of each research objective.

Three additional topics, outside of the strict interpretation of items for direct consideration, but with important aspects in relation to the utilization of genetic resources, were discussed: a) the need for more research on the physiology of tuberization; b) how CIP intends to use its Outreach program to test new potato genotypes in tropical areas; and, c) the possi-

bilities and advantages of growing potato crops from true (botanical) seed.

In introductory remarks, Dr. P.R. Rowe, Head, Department of Breeding and Genetics outlined the two functions of the Department:

1) To maintain, distribute, and coordinate the evaluation of the potato germ plasm collection of CIP, and

2) To utilize all available genetic resources of potatoes to synthesize segregating populations or clones that will solve problems of potato production.

To meet the challenge of creating potato clones with increased specific and general adaptation, potato breeders need to utilize the greatest possible sample of genetic diversity. For this reason, much emphasis is being given in the early stages of development on efforts to develop a large, well-documented germ plasm collection. This material forms the genetic base for almost all programs in CIP and much of the future success of CIP programs well depend upon the proper utilization of these genetic resources.

The efforts of CIP to collect potatoes are based on plans developed by a planning conference in January 1973. This plan calls for the systematic collection of native cultivars in the countries of Mexico, Central and South America. The expeditions for 1974 are summarized as follows:

1)	Hawkes/van Harten/Landeo	Cuzco, Puno; Bolivia; Argentina. March and April.
2)	Hjerting/Aguilar	Huancavelica, Junín. March and April.
3)	Jackson	Cajamarca. May.
4)	Huaman	Piura. May.
5)	Ochoa/Egusquiza	Arequipa. April.
6)	Ochoa/Blanco	Cuzco. May.
7)	Ochoa	Paso, Huánuco. May and June.

Also a short organizing visit to Guatemala and Mexico by Ochoa in July or August is planned.

IV. MAINTENANCE

In April, 1974, the germ plasm collection included 2650 entries of cultivars that have been given accession numbers. An additional 1900 of recent expeditions are being examined prior to the assignment of accession numbers. All primitive cultivars are maintained asexually as clones at this time. As more information about these clones is developed by CIP scientists, duplicates will be eliminated and a system for long-term propagation by botanical seed will be developed. Presently, open-pollinated seed is available for over 70% of the entries in the collection. Botanical seed of potatoes can be stored 15-20 years with current procedures.

The collection also includes over 900 entries of wild species. The maintenance of the wild species is being done in cooperation with the U.S. Potato Collection in Sturgeon Bay, Wisconsin. Duplicate samples of seed are shared by these two collection and seed increase is being carried out at this time in Wisconsin.

Because of the special problems that arise in the propagation of clonal material, CIP scientists are looking at tissue culture techniques as a possible aid in this work. A program to use meristem culture to free clones of pathogens has been established for use for clones that require special care and increase. In addition, CIP is looking at the use of tissue culture technique as a means of long-term storage and as a means of distributing genotypes in the future. Work on tissue culture is also the subject of special project requests for funding.

V. DOCUMENTATION

Data of several types are available for entries in the collection. At this time, data are kept in a manually operated system. However, an active program to determine the proper computor data processing system is underway. The Center was visited by the consulting team that is evaluating all computor needs of International Centers; their recommendations will influence the development of the computor system for CIP. Meanwhile, CIP and other major potato collections have collaborated with Dr. David

Rogers of FAO on a pilot project to evaluate the effectiveness of a particular data processing system. CIP intends to collaborate on the development of a uniform documentation system. A proposal for special project funding has been developed to cover the high initial costs of implementing a computor system.

The main research projects of the Department of Breeding and Genetics are:

1) The maintenance, distribution and evaluation of potato germ plasm.

The collection of germ plasm is under a five-year plan that was developed by a workshop held in January. The introduction of clones and seed from other breeding programs is an effort to bring in material to use in countries in the temperate areas of the world where the Center may be concerned. The immediate goal is to provide full documentation for each entry in the collection. This will include place of origin, chromosome number, species name and accumulated screening data. At the earliest possible time, an inventory of the collection will be distributed so that the CIP collection can be used more readily by all researchers. Many CIP scientists are cooperating in the evaluation of the collection.

2) The development of clones with resistance to bacterial wilt.

The Phureja source of resistance to Pseudonomas solanacearum is being used to develop clones with resistance to this disease and with adaptation to other conditions in areas where bacterial wilt is a serious problem. Clones that combine resistance to wilt and late blight are being tested in several countries. As the result of plans made at a workshop on bacterial wilt, a plan for an international test of clones has been initiated. A contract project with Wisconsin (L. Sequeira) provides the basis for the orderly preliminary screening of new material for testing in the field and is developing new information on the genetics of resistance.

3) Adaptation and utilization of potato populations in breeding.

The breeding and genetics program has the responsibility of synthesizing the diverse genetic resources into potentially useful genetic combinations. The overall goal is to produce populations from which we may select clones for a wide range of environments. Contract projects are being used to increase efforts

to use fore of the genetic resources of the potato. A population of Andigena is being selected in New York (R.L. Plaisted). Likewise, a population Phureja and Stenotomum is being selected in North Carolina (F.L. Haynes). Both projects are now testing clones in Peru at high and low elevations. A contract to concentrate more effort on Phureja is being developed in Peru. (F. de la Puente). A project on new breeding techniques is being conducted in Wisconsin (S.T. Peloquin). A project to utilize the wild species in Mexico mainly as new sources of late blight resistance has been initiated (J.G. Th. Hermsen). Core scientists in breeding will take the material developed by the linkage projects and the superior genotypes that are discovered by other scientists in CIP and make crosses and select the best material for testing in Peru and other countries.

In addition to efforts to improve and utilize the germ plasm from Mexico and the Andean Region, a collection of Tuberosum clones from the Northern Hemisphere has been accumulated. These clones, with many years of breeding behind them, represent sources of quality and disease resistance that can be used directly or as parents in certain potato growing areas that are of interest to CIP. These clones will also be used in crosses with improved Andigena and Stenotomum clones to gain maximum hybrid vigor.

4) Evaluation of advanced clones, possible parental clones, and from the germ plasm collection for nutritional quality factors.

5) Analytical studies for protein analysis of potatoes.

These projects have been developed after the Planning Conference on potato nutrition that was held in Lima in December, 1973. It is clear that there is no general agreement on the techniques to be used for large scale testing of protein content. For this reason, a project to evaluate analytical techniques will be conducted at the same time as the work to evaluate material now in the program of CIP. First efforts will be directed towards the definition of the nutritional value of clones currently used in production and for those clones that will likely be used in the near future. Once these values are established, work on evaluating the genetic potential for improvement can begin. It is likely that clones with more extensive levels of variation can be detected in the germ plasm collection, and these will be incorporated into the breeding program.

6) Selection and breeding of potato clones with frost resistance.

The need for potato varieties with resistance to frost is well recognized. However, the lack of good testing procedures have limited progress in projects all over the world. For this reason, a breeding project on frost resistance was not fully activated until after a Planning Conference on frost resistance that was held in February. A freezing test that seems reliable and that has reasonable capacity is being used.

7) Genetics and breeding for resistance to Heterodera rostochiensis, in clones of S. tuberosum spp. andigena.

Breeding for resistance to the cyst nematode is limited because of the need for more information concerning sources of resistance, the variation in the nematode, and proper testing techniques for large populations. At this time, preliminary work is being done as part of an M. S. thesis project. Clones thought to be resistant to two different nematode populations have been crossed and the progeny will be used to gather initial evidence on inheritance of resistance.

8) Control of Late Blight - Breeding for resistance.

A Planning Conference in August, 1973, discussed the problems of control of late blight. The results of that Conference have been used in the development of this project. Entries in the germ plasm collection are being screened to find possible new sources of resistance. Meanwhile, clones isolated by the testing program in Mexico will serve as an immediate source of resistance in areas where these are adapted.

VI. UTILIZATION OF THE CULTIVATED DIPLOIDS

The cultivated diploid potatoes, groups Phureja and Stenotomum, deserve much more attention than they have received. From the standpoint of organized efforts toward improvement, they have largely been neglected in favor of the tetraploids of Groups Andigena and Tuberosum. In recent years however, there has been increased interest in the possibilities of breeding potatoes at the diploid level. The research of Hougas and Peloquin and their co-

workers have stimulated this interest and they have presented most of the arguments favoring breeding at the diploid level.

In considering breeding at the diploid level, emphasis is usually placed on the utilization of haploids that have been derived from the cultivated tetraploids. The cultivated diploid species have been considered primarily as sources of disease and insect resistance to be utilized as non-recurrent parents in backcross programs. Little systematic efforts has been made to improve these species themselves. For example, the diploid clones currently being grown commercially in South America are largely unimproved native cultivars.

This material is a largely untapped reserve of genetic potential for greater production. New clones selected for adaptation to specific environments and for higher yields incorporated with other important traits found in these diploids would be a major contribution to potato production for both the highland and lowland tropics.

Many of the valuable traits found in the diploids have been listed below. As is usual emphasis has been placed on resistance to diseases and pests. While these are valuable characters, we should recognize that there are other traits which may prove to be equally as valuable as many of the resistance factors.

Disease Resistance:

Virus A	phu
Virus X	phu
Virus Y	phu, stn
Virus Leafroll	phu, stn
Bacterial wilt (*Pseudomonas solanacearum*)	phu, stn
Ring rot (*Corynebacterium sepedonicum*)	phu
Late blight (*Phytophthora infestans*)	phu
Verticillium wilt (*V. albo-atrum*)	phu

Insect Resistance:

Flea bettle (Epitrix spp.)	phu
Aphids	phu

Nematode Resistance:

Golden nematode (Heterodera rostochiensis)	phu
Other cyst nematodes	phu, stn

Frost Resistance:

Found in S. ajanhuiri, S. phureja

High Dry Matter:

Very high levels found in both phu, stn.

One very important character is total solids or dry matter content of tubers. In North America a plateau has been reached in breeding for increased dry matter percentage. It seems that we need new sources of genetic variation for this character as well as several others. An example of this is indicated in the work of Plaisted in which a program of recurrent selection for increased dry matter provided minimal progress in increasing dry matter percentage. In North Carolina, the average dry matter percentage for Tuberosum clones is between 17.0 and 17.5 percent and the highest clones about 19.5 percent. The range in dry matter for two families of Phureja which have been evaluated is:

Family 1	N = 18 clones	X= 19.80
	Range was 15.4 to 24.8, 7 clones over 20%.	
Family 2	N = 16 clones	X= 19.05
	Range was 15.6 to 26.5, 7 clones over 20%.	

In other lots of the same base population grown in Peru, the mean for 60 clones was 23.5%, and the range was 18.4% to 31.6%.

It may be argued that dry matter percentage is less important to developing countries than total yield of dry matter. This is quite true, but it is possible that the highest potential is in high yielding clones that also have a high percentage of dry matter.

Another important consideration is that of hybrid vigor. How soon we may begin to exploit the full potential of hybrid vigor depends on several factors. From the work of Plaisted; Mendiburu and Peloquin; Rowe; Haynes; and others, it appears highly probable that the full utilization of hybrid vigor will depend primarily on how much effort is expended in the identification of parental combinations with high specific combining ability from among adapted clones. There is no doubt that heterosis will be systematically exploited in the near future.

VII. UTILIZATION OF CULTIVATED TETRAPOLIDS

ANDIGENA

1. Useful Characteristics.

   a. Yield of tubers.

      (1) Andean region. An irreplaceable reservoir of genetic variability exists which is subject to loss as improved varieties become available. National programs have only touched the surface of the potential for hybridization and selection. Hybrids with selected Tuberosum may prove useful.

      (2) Temperate regions. Tuberosum germ plasm is very highly selected with limited range in new potential. Andigena is the best source for an extensive infusion of new variability. Preliminary selection of the Andigena is needed to remove the portion of variability which transmits undesirable traits. Tuberosum x Andigena hybrids will result in a lower frequency of selection but a higher potential for yield. A mean progeny advantage of selected Andigena in hybrid com-

bination with Tuberosum over Tuberosum x Tuberosum progenies tested in temperate regions has been reported to be 20% by Howard, 50% by Paxman, 13% by Glendinning, 34% by Tarn and Tai, and 15-19% by Cubillos and Plaisted. Unselected Andigena in hybrid combination with Tuberosum is too late in maturity so yields are less than intra-tuberosum progenies. Consequently the ultimate hybrid advantage should be greater than the reported statistics. A thesis by Cubillos shows that the expression of heterosis is related to day length with maximum heterosis of 30% at 13 hours mean day length in the current stage of selection.

(3) Other regions of world production.

(a) "Normal" temperature during tuberization. While the day length dependency of heterosis is Tuberosum X Andigena hybrids has yet to be confirmed, it suggests the capability of producing Andigena populations with various levels of selection for adaptation to long days and producting hybrid populations with optimum fit to specific latitudes, given the months of the growing season.

Another possibility is that in these selected Andigena populations there are clones which are neutral to day length expression. Experience has shown there are Tuberosum cultivars that are day length neutral. Selection under short day conditions of a diverse base of Tuberosum germ plasm could produce a corresponding population that would be useful in hybrid combination with the day length neutral Andigena population. If day length specificity has no intrinsic advantage, hybrids of this type would be widely useful.

(b) Warmer than "normal" climates. Within reasonable limits, variation in ability to tuberize under higher temperatures appears to exist within Andigena as well as variation for many other traits. Special programs of selection for this ability combined with resistance for the diseases encountered under these conditions should prove fruitful.

b. Day-Length Sensitivity.

Since Tuberosum clones are known that are insensitive to day length, it is likely the same is true within Andigena . The CIP trials being conducted at Huancayo (Peru), Toluca (Mexico) and Ithaca (U.S.A.) in 1974 are designed to indicate whether selection of Andigena populations under long day conditions will achieve this.

c. Maturity.

Maturity is confounded with day-length sensitivity, but is not totally determined by it. If they were needed for specific cropping patterns, Andigena with earlier maturity could be produced. It may be that the total yield per crop of the longer season varieties might be greater than of the shorter season varieties, though this is not a certainty, but it is likely that yield improvements in terms of number of days the crop occupies the land would be achieved.

d. Range of Adaptation.

The plasticity of Andigena for its range of adaptation has been under-rated. It should also be noted that to take advantage of this value requires an extensive effort in cyclic selection. Cubillo's trials with CIP at Peru, Colombia, Mexico, and New York produced results indicating greater stability for the inter-group hybrids than either intra group Andigena or Tuberosum populations, where stability is defined as deviations from the expected linear performance over locations. For those who prefer to define stability as a slope of 1.0 for variety performance plotted against location performance, the intra Andigena population was the most stable. The interpretation for this range of environments needs caution. Even though combinations of Tuberosum parents based on tuber set and tuber size has produced no evidence of merit, these factors appear to influence the heterosis of the Tuberosum x Andigena hybrids over the range of locations evaluated in Cubillos' CIP trials.

e. Disease Resistance.

(1) Late Blight. Andigena has had a reputation in temperate regions for being more susceptable to _Phytophthora infestans_ than most Tuberosum varieties. This has been a barrier to its utilization in temperate climate breeding programs. Work by Thurston, Estrada, and others in South America and by Simmonds and Thurston in temperate areas has shown that forms with high levels of field resistance can be produced. The fifth cycle of the

Cornell-CIP population of Andigena was tested in Toluca, Mexico in 1973 and 37% were rated 3 or better. A sample of clones including several rated as susceptable in Mexico were grown under conditions of an artificial epiphytotic at Ithaca. All Andigena clones remained blight free while Sebago, Kennebec, Katahdin, and several other Tuberosum varieties were totally devastated.

(2) Potato Virus Y. PVY has been a scourge of two separate Andigena populations at about the same stage of selection in Ithaca. This has not been true of Tuberosum populations grown at the same location. This has produced the impression of special susceptibility to PVY in Andigena. These same epiphytotics of PVY have revealed genetic resistance of the extreme resistance or immunity form. Attempts to infect these clones by aphids, grafting, and mechanical infection have failed. Resistance appears to be due to a single dominant allele. A few clones have shown the hypersensitive reaction of USDA 41956. The current cycle of the Cornell-CIP Andigena population has 61% of the clones with the immune reaction.

(3) Potato Virus X. Experience such as Thurston's in Colombia indicates a relative high frequency of resistance to PVX in andigena cultivars. This is borne out in the Cornell-CIP population in which 86% of the last selections are immune or extremely resistant. Except for that which may have occurred in the first cycle, there has been no selection for PVX resistance.

(4) Leaf Roll Virus. Unknown.

(5) Potato Virus S. Resistance in Andigena reported (see Position Paper, Appendix I).

(6) Potato Spindle Tuber Virus. Unknown.

(7) Bacterial Wilt or Brown rot. The _phureja_ source of resistance has been combined with blight resistant clones of Andigena. The offspring have been screened for resistance to late blight and the K60 strain of brown rot. The survivors will be multiplied (uninoculated parent clone sources) and tested at several locations for both blight and endemic brown rot. (A Cornell-CIP project).

(8) Common scab. The Position Paper refers to reports of resistance in Andigena. Resistant clones have been identified in the Cornell-CIP population. Data are not yet on the proportion which is resistant. These should be a valuable addition to the limited Tuberosum sources of resistance.

(9) Wart. The Position Paper cites references to resistance in Andigena. The Cornell-CIP population will be screened by Proudfoot in Newfoundland in 1974.

(10) Verticillium Wilt. A partial search of the Cornell-CIP population has produced clones resistant to a mixture of _V. albo-atrum_ and _V. dahliae_. A more extensive examination will be made in 1974.

f. Insect Resistance.

(1) Aphids. Resistance has been reported in Andigena to both _Myzus persicae_ and _Macrosiphum euphorbiae_. The Cornell-CIP population has been evaluated in one location as single spaced hills; 21% had low levels of infestation. These need replicated testing in 1974.

(2) Leaf hoppers (Empoasca). The position paper refers to published reports of resistance. The Cornell-CIP population was evaluated at Ithaca and Beltsville, Maryland in 1973. Resistant clones were identified at each location, but there was considerable inconsistency. The most promising clones will be retested in 1974.

(3) Colorado Potato Beetle (_Leptinotarsa decemlineata_). No published reports of resistance in Andigena and a test of the Cornell-CIP population in Maryland in 1973 produced no indication of resistance. A more broadly based population will be re-evaluated in New York and Maryland in 1974.

g. Nematode Resistance.

(1) Potato Cyst Nematode (Heterodera). The resistance found by Ellenby has been used extensively in nematode resistant breeding programs. Mayer at CIP and Ministerio de Agricultura, Peru, has evaluated a large number of andigena at three locations in Peru and identified additional

sources of resistance to an unidentified range of races. A gene, H_3, has been identified which gives resistance to H. pallida.

(2) Root Knot Nematodes (Meloidogyne spp.). As shown in the position paper, Ross and Rowe report resistance to root knot nematodes in some Andigena clones. The Cornell-CIP population was tested with four species of Meloidogyne and 13% were resistant.

(3) Root Lesion Nematode (Pratylenchus penetrans). No reports known of resistance in Andigena; however, several Tuberosum clones with the H_1 gene for cyst nematode resistance also have resistance to Pratylenchus in New York tests.

h. Dormancy.

Scientists in South America who are familiar with Andigena report greater dormancy in those clones than in Tuberosum clones. The Cornell-CIP population verifies that extremes in dormancy exist in Andigena beyond that encountered in Tuberosum. Four out of 300 clones, held at 70°F from harvest in September, had not sprouted by March 15. It is also true that there are some with very short dormancy. As with so many traits, the Andigena population displays a wide range in variability.

i. Vine Type.

When Andigena is grown in temperate latitudes, it has a vine growth which has been characterized by Simmonds. Both at Pentlandfield and Ithaca, selection for cropping ability has brought about a concurrent increase in proportion of the clones which have a Tuberosum-like foliage.

j. Chipping Ability.

Tubers of the Cornell-CIP population were held at 40° and 50°F and then chipped after two and 6 weeks of reconditioning at 65°F. Twenty-four percent of the clones produced chips of acceptable color under these 4 storage and reconditioning environments.

k. Flavor.

This important attribute has not been given an evaluation that can be cited and tested. Nevertheless, enough unsolicited and independent opinions have been expressed in favor of the flavor of Andigena varieties that this difference must be considered.

2. Strategy for Utilization.

a. Creation of heterogeneous populations of Andigena.

(1) Master population at CIP designed to foster maximum panmixis among all known sources of Andigena.

(2) One or more populations selected for adaptation to long day - temperate latitudes.

(3) One or more populations selected for ability to tuberize under high temperatures.

(4) Populations with special attributes. (May be separate or may be a component of one of the first 3 populations.)

(a) Field resistance to late blight.

(b) Virus resistant.

(c) Resistant to root knot nematode, brown rot, and late blight; probably in combination with ability to tuberize under high temperatures.

(d) Insensitive to day length.

b. Creation of a broadly based Tuberosum population selected for adaptation to low latitude or insensitive to day length.

c. Creation of bulk hybrid populations between the Andigena and the Tuberosum populations.

d. Distribution of bulk lots of seed of any of these populations to the outreach programs for selection for specific adaptation or to potato breeders at National programs for the same purpose.

VIII. UTILIZATION OF CULTIVATED TETRAPLOIDS

TUBEROSUM

Useful Characteristics

Many of the useful characteristics found within Solanum tuberosum spp. tuberosum or the now wider group of Tuberosum materials which includes genetic material from S. demissum, S. andigena, S. stoloniferum, etc. are included in the position paper (Appendix I). Additional possible characteristics of importance within Tuberosum include resistance to skinning and bruising, protein content, vitamin C content, tolerance to heat in tuber production, resistance to greening, leafspot (Macrophoma) and smut (Thecaphora solani).

In broadest terms, Tuberosum has tuber size, tuber appearance, maturity, relative daylength neutrality, and highly selected building blocks possessing a wide range of agronomic and pest resistant characteristics to offer for breeding purposes.

Strategy for Utilization.

Variety development using Tuberosum

1. Traditional Tuberosum breeding
2. Tuberosum-Andigena complimentation
3. DH and 4x-2x applications

Points for discussion

1. In the position paper it is stated that: "Even when resistance has been found, it is not being used to any extent in breeding programs". This is probably an overstatement, but there is enough truth in it to strike a responsive chord with those involved in variety development. The major reason for this state of affairs is the difficulty breeders have in systematically utilizing characteristics which are important. The fact that most discard approximately 90% of populations in first selection, and

the fact that perhaps only one individual in 2-500,000 is of sufficient merit for release as a variety, are monuments to this state of affairs.

Breeders are lacking not genetic resources but rather an ability to manage in an efficient manner the genetic resources already at hand. For this reason, a center like CIP should consider making their resources available as a "package", in order to maximize the possibility of successful use of their distributed materials. The package would contain the genetic stock, a phenotypic description of that stock and a suggested strategy for utilization based on the breeding behavior of the material. At the present state of knowledge, the third item in the package could not be adequate or complete. It might contain a description of a procedure for evaluating the characteristic, comments on what is known of associated characteristics, and information on heritability, stability and combining ability if known. The package thus becomes a more useful entity than the genetic stock alone. However, there is still only limited knowledge of how to manipulate these genetic resources and this lack of knowledge may well be the limiting factor in their utilization.

2. Is research on potato breeding methods a valid area of investigation at CIP? CIP does not intend to breed varieties per se, but rather to rely on national programs to perform this task. The successful utilization of the genetic resources at CIP thus rests in the hands of the breeders in the national programs and their success depends on the state of development of potato breeding methodology at the present time. This consideration could effect the priority CIP might wish to place on research on potato breeding methodology.

Stated in broadest terms the following topics are worthy of consideration for additional research:

a) Component selection e.g. Yield-number of stems, date of tuberization, number of tubers, tuber bulking rate, size of tubers.

b) Indirect selection methods

c) Selection efficiency

d) Stability

e) Heritability

f) Screening procedures

g) Radical changes in present production methods

1. Direct planting of botanical seed

2. Analysis of production systems to consider significant changes in plant type.

IX. UTILIZATION OF THE CULTIVATED TRIPLOID AND PENTAPLOID POTATO SPECIES

The cultivated triploid and pentaploid potato species, according to Hawkes, include the S. juzepczukii Buk; S. x chaucha Juz et. Buk., and S. x curtilobum Juz et Buk.

1. Useful characteristics

Triploid cultivated species

In contrast to certain wild species, the triploid cultivars are numerous and fully distributed. They constitute a high percentage in some populations due to the advantage of selection under cultivation conditions. The species listed below are considered in this group.

Solanum x juzepczukii ($2n = 3x = 36$).

This species is normally cultivated at high altitudes (3,400 - 4,300 m.). It is distributed from the central part of Peru up to the South of Bolivia and part of Northwest of Argentina. According to Hawkes, it is a hybridogenic species between S. acaule ($2n = 4x = 48$), a wild tetraploid species, and S. stenotomum ($2n = 2x = 24$), a diploid cultivated species. It is cultivated for the production of "chuño" and "moraya".

The main characteristics of this species are:

1. Resistance to Synchitrium endobioticum; Alternaria solani; Heterodera rostochiensis; and to frost.

2. Hypersensitivity to virus "X", and early maturity.

This species is highly sterile. It has a photoperiodic reaction to short days and reaches yields of 15 to 20, tonnes/ha under conditions of the highlands of Peru.

Solanum x _chaucha_ (2n = 3x = 36).

It is distributed from the central part of Peru to the central part of Bolivia and cultivated at medium altitudes (2,500 - 3,200 m). Hawkes reported some of these cultivars were found in Argentina. It is considered that this variety has been originated through natural crosses of the two cultivated species of _S. tuberosum_ ssp. _andigena_ and _S. stenotomum_.

Following are the main characteristics for this species:

1. Immunity to _Synchitrium endobioticum_ and virus "X".
2. Resistance to _Phytophthora infestans_.
3. Earliness.
4. High dry matter and protein content with excellent flavor.

This species is highly sterile and accounts for approximately 1/6 of the cultivars in mixed cultivations in Peru. The species has a good range of variability. Cultivars of this species, such as Huayro, Amarilla de Tarma, Huayrush,etc., are considered as the most marketable varieties in the center of Peru.

Pentaploid cultivated species.

_S._ x _curtilobum_ (2n = 5x = 60).

This species is cultivated at high altitudes from the central part of Peru (Ancash) up to the South of Bolivia and between the frontier of Argentina and Bolivia. This species is indicated as a complex hybrid, developed from natural crosses between _S. juzepczukii_ (which would produce 2n gametes) and _S. tuberosum_ ssp. _andigena_. This species might contain two sets of 12 chromosomes from _S. acaule_, one set from _S. stenotomum_ and two sets from _S. tuberosum_ spp. _andigena_.

The main characteristics of this species are:

1. Resistance to *Phytophthora infestans*; *Synchitrium endobioticum*.

2. Hypersensitivity to virus "X" and Virus "Y".

3. High dry matter and protein content.

4. Earliness.

This species has low fertility and is self-fertile. Berries are produced from free pollination and seed coming from these berries have chromosome numbers ranging from 53 to 54.

Ochoa made some crosses between this species and *S.tuberosum* ssp. *andigena*, using it as male and female, and had success in both cases. The hybrids obtained from these crosses showed (according to Ochoa) performances of 20,000 - 30,000 kg/ha. under Puno and Huancayo conditions (3,800 and 3,300-3,900 m respectively).

Zhukovskii indicates that when this species was crossed as a female parent to *S. tuberosum* ssp. *andigena*, a few seeds were produced. The hybrids were sterile, showed heterosis, and had resistance to temperatures of -1. C to -2. C and had the Andigena flavor. Bukasov reported that some hybrids of this species have good performance and are resistant to temperatures of -4.C and -5.C.

Hawkes considers that although this species is predominantly a short-day type, it has cultivars with photoperiodic reaction to long-days.

2. Strategy for utilization

With the purpose of proposing strategy for utilization of triploid and pentaploid cultivated varieties, the following points are to be taken into consideration:

1. These species are an important part of potato production in the Andean area (Peru-Bolivia). These species are popular in this area: *S. chaucha* for its quality, and *S. juzepczukii* and *S. curtilobum* for frost resistance and for utilization for "Chuño" and "Moraya". Puno (Peru) cultivates almost 8,000 ha. of bitter potatoes.

2. Some useful characteristics for these species have been previously listed.

3. Although there are fertility problems, crosses using them as male and female progenitors have been done as in the case of *S. curtilobum* (male) and *S. chaucha* and *S. juzepczukii* (female).

4. The wide distribution of some triploid cultivars such as *S. x chaucha* - cultivar Huayro for example, makes us think that they have species advantages under selection, not yet explained, and that might be profitable for improvement programs.

5. There is a limited number of collections of these species in the CIP germ plasm bank and in some other programs. There are 70 collections of *S. curtilobum*, 42 of *S. juzepczukii* and 120 of *S. chaucha*.

X. UTILIZATION OF NON-CULTIVATED (WILD) SPECIES

Introduction

Like species in all plant families, *Solanum* species have built up inter-specific barriers, which prevent them from being submerged in one large *Solanum* - gene pool. A breeder who likes to include wild species in his breeding programme has to break the barriers between wild and cultivated species in order to make the genes accessible which are known to be stored in the wild species.

Because of the usually large differences between wild and cultivated species the plant breeder has to carry out many back-crosses in order to reach the varietal level after the original interspecific cross. This is a great drawback, not only because repeated backcrossing and repeated testing are time-consuming, but also because polygenically determined characters may be lost to a great extent during the backcrossing procedure. Therefore the recommendation of the CIP workshop in January 1973, that cultivated forms should be given first priority, is a logical one. It holds true for all crops, not only for potato. This recommendation may be extended to non-cultivated forms as follows:

When for certain characters reliance had to be placed upon non-cultivated species, those forms should be given priority, which are most closely related (or have been made most related) to the cultivated forms.

There are a number of independent reports on the probable contribution of polygenes from wild species. These reports are mainly related to yield and resistance to leaf roll.

When discussing useful characteristics, or rather, useful genes from wild species, there are two characters based on polygenes: yield and resistance to leaf roll. There are a number of independent reports on a probable contribution of genes for yield from wild species. Bukasov, Toxopeus and Ross claimed extra high yields in S. demissum derivatives, while Huijsman has obtained a number of S. vernei - derived clones with surprisingly high yielding ability. Baerecke and Ross reported a greater resistance to leafroll-infection in hybrids, derived from S. chacoense, S.acaule Andigena and S. demissum than could be found in pure Tuberosum varieties, though resistance in the wild species themselves was not found. Both the high yields and the higher leafroll-resistance are thought to be due possibly to the complementary or other kinds of interaction between genes from the wild species and the cultivated species.

These observations are more or less incidental. However, if through systematic research they are confirmed, then the value of wild species for breeding polygenically determined characters (yield, quality characters, adaptability, horizontal resistances) would clearly be established. These observations on polygenic characters also support the hypothesis that non-race specific resistance genes from different species may be expected to differ.

Successful systematic utilization of wild species has generally been restricted to rather simply inherited characters: race-specific resistance to Phytophthora, pathotype-specific resistance to Heterodera rostochiensis and non-specific, monogenically, dominant immunity from the viruses X, Y and A. Typical examples of non-successful systematic attempts to utilize wild species are e.g.: frost resistance from S. acaule by Mastenbroek (due to difficult testing and complicated inheritance), resistance to Colorado beetle from S.chacoense by Torka and from S. demissum by Toxopeus (due to complicated inheritance and successful chemical control).

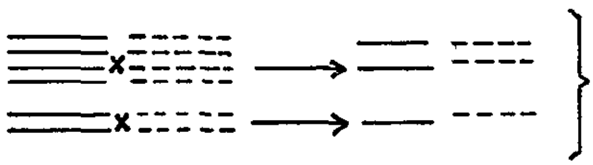
Genes for characters which are widespread in cultivated species, in principle need not be searched for in wild species.

However, characters which occur abundantly in cultivated species should be taken into account in evaluating wild species. The more useful and the more *Tuberosum*-like characters a wild species has, the lower is the number of backcrosses to *Tuberosum* which have to be made.

Fundamental statements and recommendations and strategy for utilization.

In the introduction it was pointed out that interspecific barriers, being fundamental for the existence of these species, are also unavoidable for a breeder who has to break or overcome these barriers. In addition it was pointed out that the number of backcrosses to be made is a great drawback for the utilization of wild species. Repeated backcrosses and testings take much time. Furthermore it is extremely difficult to keep the level of polygenically determined characters at an acceptable level. Therefore it was recommended to choose those wild forms which can be nobilized most quickly, in other words which are so closely related to Tuberosum that few backcrosses are needed.

Another measure to speed up nobilization is to breed at the diploid level. This can be demonstrated with *S. vernei*. Usually breeders double the chromosome number of *vernei* to promote crossability with *S. tuberosum*. It is advisable to cross *S. vernei* with selected diploid *S. tuberosum*.



If there is any preferential pairing this limits gene exchange between species and delays nobilization.

Without preferential pairing in the tetraploid, undesirable genes will disappear more slowly from the population, because besides pairing, also and occur in that case.

In order to further speed up the nobilization process (and decrease the number of backcrosses needed, it may be recommended that "pre-breeding" be carried out within wild species. Pre-breeding is a procedure comparable to the adaptation programmes which are going on in Andigena and in cultivated diploids.

Such pre-breeding programme should also include:

- a thorough evaluation of desired characters within the wild species before crossing with cultivated species;
- a study of the genetics of such characters within the wild species in order to avoid erratic genetic ratios due to interspecific barriers and genic or genomic interactions;
- concentrating genes of the desired characters within wild species, particularly when inheritance is more or less polygenic;
- combining, within the species, different valuable characters which are scattered over different accessions of that species.

The result of a pre-breeding programme may be highly valuable clones, which are environmentally adapted and comprise concentrated genotypes for valuable characters, while also the genetics of these characters may have been clarified. Such clones are good starting material for breeding at the diploid level (or amphidiploid level). Among the species which may warrant intensive research, are: S. chacoense, S.demissum, S. acaule, S. bulbocastanum and also wild species from series Tuberosa like S. vernei.

Principle of "resistance columns"

This method is based on the assumption, that resistance to a certain disease, in different species is based on different genes. The way of introducing a high level of resistance into cultivated forms, according to our principle of resistance columns, can generally be explained as follows:

Breed from each resistance-source resistant nobilized clones in such a way that each clone (or group of clones) derives its resistance from a different species. After having built these separate "nobilized" clones ("columns of resistance"), they should be intercrossed in order to combine the resistance genes from different species. According to this philosophy one should not be content with one source of resistance, even not with different accessions of one species. For Pseudomonas resistance S. chacoense, Andigena and perhaps S. pinnatisectum should be studied, in addition to Phureja.

<u>A Programme including pre-breeding, column-building and convergent breeding columns.</u>

		Species 1	Character x
pre-breeding	1	Test many accessions and Intercross high x high, high x low, low x low	
column building	2	Determine inheritance Select best sib-clones Cross these best clones with <u>S. tuberosum</u> Select best F_1 plants Backcross	
	3	Repeat procedure for backcross generation (⟶ column from species 1)	
		Build at the same time columns from other species	
combination & convergent breeding (upgrading level	4	Combine the columns at the "nobilized" level	
	5	Test progenies, select the very best ones Continue convergent breeding according to the scheme:	

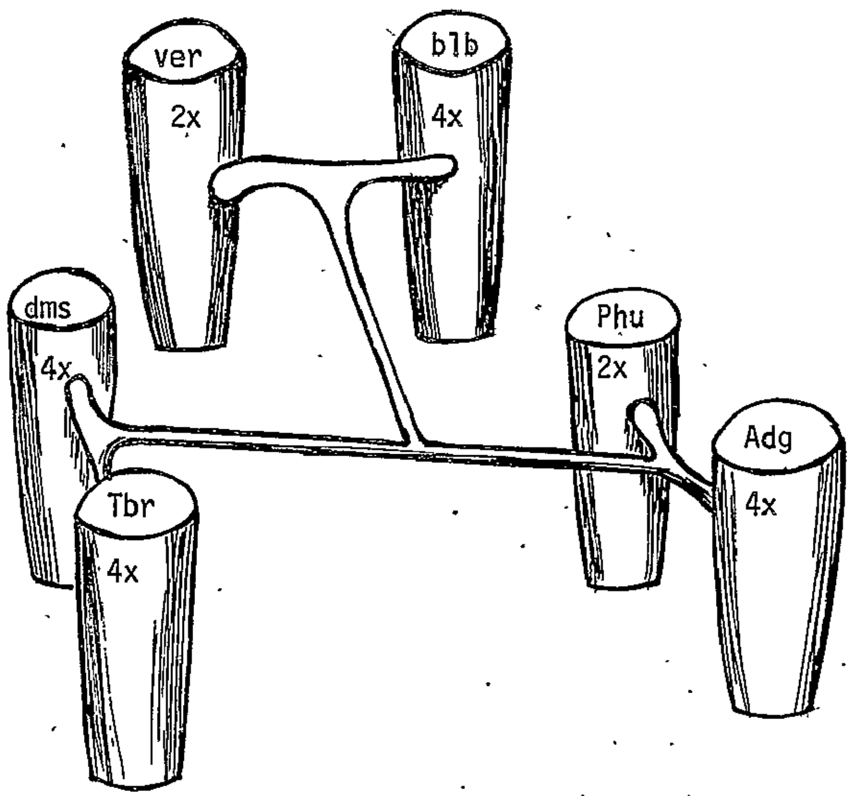
1 2 3 4 .... n

1.2 3.4 ......(n - 1) n

1.2.3.4. etc.

When testing has to be carried out on tubers, the pre-breeding part should be carried out on plants grown under short day conditions.

<u>Illustration of columns for Phytophthora resistance</u>



XI. CONSERVATION OF POTATO GERM PLASM

1. Clonal propagation

Initial discussion on the conservation of germ plasm for future use was concerned with field collecting. The CIP approach was outlined, the general technique being to collect two or three tubers of each distinctive morphotype in a field. If a field had been harvested it was necessary to rely on the farmer for tuber identification, the Indian name occasionally being provided. A small group of tubers from similar plants are assigned an accession number. Every effort is made through visual observations in 15 hill plots to ascertain the purity of an accession. It was noted that flowering is general in most accessions and over 70 per cent of accession readily set seed.

2. Bulk seed conservation

The possibility of bulk seed propagation as a method of germ plasm conservation was discussed at length. The obvious difficulty was in reisolating a desired recombinant. A method which tended to minimize genetic drift was outlined as follows:

Twenty numbered plants were crossed, 1 x 2; 3 x 4; 5 x 6; 7 x 8; etc., the odd numbered plants serving as female the even numbered plants as males; an equal number of seeds are collected from each cross and bulked.

In another approach bulked pollen from 24 plants was used to pollinate diploids without emasculation and equal numbers of seed collected from each plant and bulked. The usefulness of bulking on the basis of specific requirement was discussed, e.g. nematode resistance; virus resistance.

The techniques of storing botanical seed was reviewed. Low moisture (5%) storage in impervious plastic packages, 50 seeds/pkg. at a temperature of 3-4°C permitted retention of viability normally for 10-20 years. It was noted, however, that some wild diploids could only be stored for a relatively short-time -- thus the need for testing for viability from time to time. A scheme for the production of botanical seed as a substitute for conventional method of seed certification is presented in Appendix 2.

It was suggested that CIP might maintain a catalog of tetraploid varieties and breeding stock and act as an international

reference source. This would be confined to maintaining lists only.

It was noted that in selfing tetraploids there may be a loss of vigor. It was also indicated that in maintaining cultivated triploids and pentaploids that it was probably sufficient to maintain parental lines so that juzepczukii and curtilobum could be resynthesized. Chaucha may be special case in which instance seed could be maintained.

In vitro techniques

Freeing selected potato clones from viruses by meristem culture was considered to be an acceptable technique. Other tissue culture techniques were viewed less favorably. It was noted that cells in culture commonly lose their ability to differentiate after prolonged culture - even if potato cells could be induced to differentiate. The possibility of obtaining shoots from callus cultures was discussed.

XII. RECOMMENDATIONS

(Priority 1, high; II intermediate; III low)

A. Diploid cultivated species

1. Resistance to *Pseudomonas solanacearum* to be combined with resistance to *P. infestans*.

(a) Pay-off in 3-5 years from work already initiated. Priority I.

(b) Screening of further lines to provide a broader genetic basis of resistance to *P. solanacearum*. Priority III (and also possibly of wild species).

2. Frost resistance emphasizing *S. ajanhuiri*; also use of frost resistant clones of *S. stenotomum* and *S. phureja*. Priority II, pay-off probably 5-10 years.

3. General adaptation for new potato growing regions and possible selection of day-neutral types in both diploid and tetraploid species. Priority I, pay-off possibly in 5 years and not more than in 10 years.

4. Diploid x dihaploid; breeding at 2x level for use in 4x hybrids - depends on progress at places other than CIP.

B. Cultivated tetraploids - Andigena

5. Resistance to virus Y; utilization of monogenic immunity. Resistance from *S. stoloniferum* to be considered as a safe-guard. Priority I, completion in under three years.

6. Resistance to races of *Synchytrium endobioticum* - program underway. Priority II, results in 3-5 years.

7. Resistance to cyst nematodes. Priority I, results in 3 years (preliminary tests, 1st year; main test, 2nd year; confirmation, 3rd year).

8. Tuberosum x Andigena crosses for production of stock for breeders. Priority I, continuous, but some results in 3-5 years. Priority II, long term but results could be in 3 years. (comparison of F_1 with F_1 x F_1; cytoplasmic effects; etc.).

C. Cultivated tetraploids - Tuberosum

9. Documentation of collections at other centres to include parentage and information on both desirable and undesirable characters: Priority II, complete within 3 years.

D. Triploid and pentaploid cultivated potatoes

10. Selection of best bitter frost resistant varieties (*S. x juzepczukii* and *curtilobum*); elimination of virus infection; increase for use. Priority I, under 5 years.

11. *S. chaucha* - no recommendation until more information available.

E. Non-cultivated species

12. Resistant to cyst-nematodes (*Heterodera* spp.); screening with particular reference to resistance to Andean pathotypes. Priority I; screening within 3 years followed by a breeding programme.

13. Utilization of further sources of resistance to <u>Phytophthora infestans</u>. Priority II; 5-10 years.

F. <u>Conservation of Genetic Resources - in vitro techniques</u>.

14. (a) Meristem culture. Priority I; continuous service.

(b) Cell and tissue culture. Speculative.

15. (a) Preserve open-pollinated seed of each clone initially; further maintenance by sib-crossing, etc.

(b) Maintain clones for evaluation; keep only those clones with valuable characters. Priority I; continuous.

16. Triploids and pentaploids I; maintain for a limited period only.

17. Wild species - maintain only as botanical seeds (triploids, see 16 above).

G. <u>General</u>

18, High production of protein per unit area; evaluation of protein quality started. Vitamin C and other factors of nutritional importance also to be considered.

19. Resistance to leaf roll - need for a wide search to find a highly heritable type of resistance. Priority I, (3-5 years).

20. Despite previous work, there is a need for more physiological work on factors influencing tuber initiation and growth with particular reference to Tuberosum x Andigena.

21. Basic research for 3-5 years followed by use of botanical seed to produce crops on a farm scale or as a substitute for conventional method of seed certification.

22. Resistance of tubers to <u>Phytophthora infestans</u>. Priority I (3-5 years).

23. Training programs for users of breeding material from CIP.

24. Establishment of a data handling center to collate data

from CIP trials; development of a common, uniform recording terminology (See Report, Appendix 3).

25. Resistance to root-knot nematodes (Meloidogyne spp); checking of suspected resistance and further screening. Priority I (3-5 years).

26. Resistance of tubers to diseases and pests.

It was recognized that many diseases and pests though locally important could not be assigned specific priority.

APPENDIX 1

THE UTILIZATION OF GENETIC RESOURCES

Position Paper for CIP Planning Conference

H.W. HOWARD

INTRODUCTION

Way back in 1936 Hudson wrote: "Potato breeding was", to use the picturesque works of Professor Bukasov himself (1932), "stewing in its own juice, using for the introduction of new varieties always the same old parents in innumerable combinations. A cul-de-sac had been reached, with many problems still unsolved, such as blight and virus diseases". The situation changed greatly after the first Russian potato collecting expeditions to Latin America in 1925-26, and Hawkes (1970) listed some 24 collecting expeditions made between 1925 and 1966 by non-Latin American countries and some 10 further collections made on behalf of (or with funds from) Latin American Governments or Universities. There is, therefore, in the potato gene banks, of which Hawkes (1970) listed four in non-Latin American countries and four in existence, or about to be set up, in Latin America (Mexico, Colombia, Peru and Argentina), a large number of clones of both cultivated and wild species.

While steps should still be taken to collect new material and to preserve it in gene banks before it disappears (the problem was considered recently in a CIP Workshop held at Lima in January 1973), it can be argued that the collecting of further material is not as important as testing the material already assembled for the characters wanted by potato breeders. It is all too easy for those in charge of potato collections only to keep the collections from disappearing and not to organize tests of disease and pest resistance, chemical composition and other characters. Without such tests, although the collections may be of considerable interest to taxonomists, they are of very little value to the breeder wishing to use new sources in the production of improved varieties. It would be interesting to know just how much time has been spent on maintaining collections and how little on testing the material in them. For at least one major collection, the only large-scale testing has been carried out be a few scientists not working at the station where the collections was maintained but at other places. Among the advantages of putting as much as possible of a collection into true seed is that it minimizes the amount of time spent in maintaining it and permits more resources to be given to the work of finding just what valuable genes are present (Howard, 1969).

The utilization of genetic resources, ie. the breeding of improved varieties, is a complex subject and is not confined to just listing the valuable characters found in the many known clones of potatoes. In plant breeding, just as in war, strategy (the choice

of operations to be attempted) must take into account tactics (the procedure adopted for carrying out a given policy). It is, for example, pointless for a potato breeder to decide he will breed a variety resistant to frost if he has neither a frost-resistant parent which can be used in crosses nor adequate tests for frost resistance to apply to the segregating progenies.

It is therefore necessary to consider carefully what is involved in potato breeding so that the type of genetic resources useful to the breeder can be identified. This it is proposed to do under the following headings: the chance of breeding a successful variety; choice of objectives; choice of parents; pollen fertility; yield; quality; disease and pest resistance; types of resistance; tests for resistance; and genetic resources.

POTATO BREEDING

The Chance of Breeding a Successful Variety

As every practical potato breeder knows only too well, but it apparently not always appreciated by many pure scientists, the chance that any seedling will become a successful variety is very small. The position has been put very clearly by Simmonds (1969):- "In framing the objectives of a potato breeding programme the first requirement is realism. The "perfect potato" does not exist and there is good reason to think that it never will. The reasons for this statement are as follows. Consider, for example, the breeding of a maincrop ware variety. A population of seedlings of the appropriate maturity range is selected for a number of characters of economic importance; the characters are assumed to be genetically independent. Suppose we select at the 10 per cent level for the following seven characters: yield, tuber shape, cracking, cooking quality, blight resistance, leaf-roll resistance and scab resistance; at the 20 per cent level for the following seven characters: tuber size, foliage type, flesh colour, resistance to gangrene, resistance to skin-spot, resistance to dry rot and resistance to black leg; and at the 50 per cent level for three characters: skin colour, resistance to wart and resistance to virus Y. The severest selection here is at 10 per cent, which is quite weak; and yet a clone which would satisfy all these 17 criteria would emerge only once in about 10 billion seedlings. If, by contrast, all 17 characters were selected very weakly at the 50 per cent level, then one selection would emerge in about 150,000 seedlings (which represents about four years' production at Pentlandfield). The conclusion is clear; one must either select for fewer characters or select less intensively. Negative correlations between characters would make effective selection even more difficult".

Choice of Objectives

Because the chances of breeding successful varieties is so small, it is obvious that the choice of breeding objectives is very important and must be considered very carefully. It may be necessary to take into account several factors in deciding which are the most important problems to be tackled and which are of relatively minor importance.

There may be one or two deficiencies in the varieties being grown which are of outstanding importance. Such deficiencies will vary from country to country. In those countries where potatoes are widely grown and where the agricultural extension services are well organized, it may be easy to obtain the necessary information. This, however, is not always so and it may need surveys and field experiments to determine the most serious problems which the breeder should tackle. For example, late blight (Phytophthora infestans) was for many years considered to be a very serious disease in England, but the survey work of Cox and Large (1960) - also quoted by Howard (1963) and Howard, Johnson, Rusell and Wolfe (1970) - showed that years of heavy blight attack were years of high yield, not low. Because the yield of potatoes in England depends largely on there being a sufficient rainfall, the heavy attack of blight in wet years was only removing that part of the crop surplus to a static requirement - this would not, of course, apply to all areas but only to the majority in England where blight is not severe until much tuber growth has taken place. Immunity (very high resistance) to wart disease (Synchytrium endobioticum)is possibly another example in western Europe at the present time - although this is demanded of all new varieties, two old susceptible varieties, Bintje in the Netherlands and King Edward in England, are very widely grown without wart being found on them. Conversely survey work in England on reductions in yield from Heterodera infestations (Brown, 1969) has emphasized the importance of breeding for resistance to this pest by showing that populations of the nematode not high enough to produce obvious symptoms on the tops were reducing yields considerably.

Although the use of resistant varieties is always the cheapest method of controlling a disease or pest, there may be circumstances where chemical control or other means is satisfactory and it is not necessary to give the potato breeder a difficult problem to solve. There may, for example, be no need to breed varieties resistant to virus diseases if good "seed" districts are available. Similarly the use of stocks raised from stem cuttings may obviate the need for varieties resistant to blackleg (Erwinia carotovara var. atroseptica), to skin spot (Oospora pustulans) and some other tuber diseases (Hardie, 1970; Calvert, 1973). Protein content is another possible example - it may be easier to produce high yielding varieties of normal protein content so that legumes could be grown on the area made vacant rather than attempt to breed potatoes with high protein content.

On the other hand it may be that in the future there will be more use of integrated control, ie. using both a resistant variety and some other method of control simultaneously. This is being used

in the Netherlands for combating cyst nematodes (Nollen and Mulder, 1969), treatment with a nematicide being combined with the use of resistant varieties. Similarly good control of late blight can be obtained in England by fungicide treatment of the foliage plus varieties which have a high resistance of tubers to infection (Howard, Johnson, Russell and Wolfe, 1970). Control of virus diseases can involve growing in a good "seed" district where there are no, or few, aphids to spread some viruses plus either resistant varieties or serological testing to control the viruses spread by leaf contact.

Choice of Parents

Having decided what criteria are wanted in new varieties, the breeder has to choose the parents which between them have the desired qualities. Normally these will include varieties of cultivated tetraploid potatoes, either Tuberosum potatoes (ie. *Solanum tuberosum* spp. *tuberosum*) in temperate zones, or Andigena potatoes (ie. *S. tuberosum* ssp. *andigena*) in tropical latitudes with day lengths not differing greatly from 12 hours.

If the varieties used in a breeding programme can be confined to the cultivated tetraploid potatoes, then most progeny will have tubers of at least fair quality and there will not be a high proportion of seedlings with bad quality as so often occurs when a wild species has been included as a parent.

If not all the desired characters can be obtained in the tetraploid group of cultivated potatoes, then it would seem to be best next to see whether the desired character or characters can be found in the diploid cultivated potatoes rather than in wild species (Howard, 1970; 1973). There is no difficulty in crossing cultivated diploids and tetraploids, and the result of such crosses is often tetraploid, not triploid, offspring (Marks, 1966). Alternatively, breeding in the future might be at the diploid level using the cultivated diploids and dihaploids of *S. tuberosum*.

If neither the tetraploid nor diploid cultivated potatoes contain all the characters wanted, then resource may have to be made to wild species. Many wild species can be crossed easily with cultivated potatoes, but there are, of course, certain groups of wild potatoes and some species which have not so far been crossed with cultivated varieties. Breeding from wild species must take longer than breeding from cultivated varieties only because a series of backcrosses to cultivateds has to be carried out. In addition, as has already been pointed out, it may be difficult to obtain adequate cooking quality. On the other hand, this is not impossible

and a number of widely grown varieties of good quality have been obtained from wild species, eq. Kennebec in the USA, Maris Peer and Pentland Dell in the UK.

Breeding from wild species does not usually involve sterility problems in the offspring which cannot be overcome. Also, with the potato being reproduced commercially by vegetative reproduction, there are no problems as in most other crops of having to obtain progeny which breed true to type from sexual reproduction.

Pollen Fertility

The lack of pollen-fertility in many Tuberosum varieties can be a major difficulty in the use of parents with the desired characters. On the whole, although pollen-sterility may arise from the interaction of the cytoplasm of one species with the nuclear genes of another (Grun. 1970a and b), it is often possible when using Andigena varieties, diploid cultivated potatoes, and wild species to obtain a high proportion of pollen-fertile offspring to use in subsequent stages of breeding programmes.

Yield

No new variety has any chance of success unless it yields as high as that of existing varieties. This again makes breeding from wild varieties a slower process usually than breeding from cultivated varieties only, but, as with quality, several varieties bred from wild species are very high yielding.

Quality

It is not proposed to discuss quality as there was a Planning Conference on Potato Quality held at CIP, Lima, in November 1973. It should also be noted that Quality will be the theme of the 1975 Triennial Conference of the European Association for Potato Research.

Disease and Pest Resistance

Most potato breeding has for many years been concerned with breeding for resistance to diseases and pests. Much has been achieved but there is still much to do. As has been emphasized previously (the Choice of Objectives), the first necessity is to identify the important diseases and pests and to determine whether the use of resistant varieties is the best method of control. It then remains to decide what type of resistance is required, whether there

are sources of resistance, and whether there are adequate tests of resistance suitable for use by breeders.

It should also be noted that the breeding of disease-and pest-resistant varieties may be the easiest way of increasing yields.

Types of Resistance

In breeding for resistance to many diseases and pests of all crops there appears to be general agreement that in the future much greater attention should be given to non-specific resistance because it is expected to be nearly always more durable than race-specific resistance. These two types of resistance are also distinguished as "horizontal. and "vertical" resistance - they were defined by van der Plank (1963, page 174) as follows: "When a variety is resistant to some races of a pathogen, we shall call the resistance vertical or perpendicular. When the resistance is evenly spread against all races, we shall call it horizontal or lateral".

Race-specific resistance is often due to a hypersensitive reaction of the host and is often controlled by major genes, eg. the *R* genes for resistance to *Phytophthora infestans*.

Non-race-specific resistance is also sometimes called field-resistance. It is often due to several causes and may be controlled by polygenes. Although it may be more durable than race-specific resistance, it may be a much more difficult type of resistance for the breeder to use, particularly if it is derived from a wild species as the polygenes will tend to be lost in a back-crossing programme.

Tolerance, ie. little reduction in yield when infected, is also considered as a type of resistance. There are, however, on the whole few investigations of tolerance.

Obviously in breeding for race-specific resistance it is necessary to know how many pathotypes (physiologic races) of the pathogen exist and how quickly new pathotypes can arise and spread. There is in addition always the possibility that some countries do not have as many pathotypes as others, particularly as many diseases and pests are confined to potatoes and not endemic outside S. America. It may also, therefore, be more difficult to breed for resistance in S. America, especially if it is of the race-specific type.

Tests for Resistance

Adequate tests are obviously necessary in searching for disease-and pest-resistance but they are just as necessary for the breeder in testing his segregating progenies. It is particularly important both in the large-scale screening of material and in the selection of progenies that the tests should be relatively simple to perform so that the rapid testing of many samples can be done.

It is also important to ensure that the material tested should be the correct type. This applies particularly to testing under the 16-18 hour day found in temperate regions of wild species, cultivated diploids, and Andigena potatoes adapted for tuber-formation under short days. Misleading results can arise from such tests.

Genetic Resources

This rather long preamble on Potato Breeding has been given before the detailed Survey of Genetic Resources because it is suggested that the latter should be realistic - there are all too many general reviews on the uses of Latin America cultivated and wild potato species and all too few which consider the problems critically and in detail.

It is suggested that particular attention should be given in considering Genetic Resources to:

(a) The importance of the disease, pest or other hazards - this will vary from country to country.

(b) Possible sources of resistance - Tuberosum, Andigena, cultivated diploids, and wild species.

(c) The type of resistance - race-specific, non-race-specific, tolerance.

(d) The inheritance of resistance, and

(e) Adequate but quick tests of resistance.

SURVEY OF GENETIC RESOURCES

Introduction

Many diseases and pests can attack potatoes and those considered below are only a selection and, moreover, a selection influenced by the author having no experience of potato growing except in western Europe. It might be useful for CIP to compile a world list of potato diseases and pests and to include in this list the importance of each disease or pest and, where possible, sources of resistance.

In compiling the data use has been made of "Plant Breeding Abstracts" from 1960 to 1973 inclusive. It was necessary to make a stringent selection of references. More useful information could no doubt have been obtained had there been time to refer also to other abstracting journals such as "Review of Plant Pathology" (formerly "Review of Applied Mycology"), "Review of Applied Entomology: Series A, Agricultural" and "Helminthological Abstracts".

Many references prior to 1960 can be found in the two publications:

Swaminathan, M.S. and Howard, H.W. (1953). "The cytology and genetics of the potato (*Solanum tuberosum*) and related species". *Bibliographia Genetica* 16, 1-192.

Howard, H.W. (1960). "Potato cytology and genetics, 1952-59". *Bibliographia Genetica* 19, 87-216.

For Latin-America countries, Montaldo (1964, 1967, 1969) has compiled the very useful lists of publications: Bibliografia Latin-American sobre Papas.

Bulletin 533 of the College of Agricultural and Life Sciences, the University of Wisconsin, Madison, Wisconsin - "Inventory of tuber-bearing *Solanum* species" by Ross, R.W. and Rowe, P.R. is very useful in listing sources of resistance in IR-1 Potato Collection. It gives, where known, resistance to:

1. viruses A, X, Y and Leaf Roll with occasional notes on others (S, Spindle Tuber, F, B, C, G, M and Tobacco Mosaic).

2. late blight (Phytophthora infestans) and Verticillium wilt with occasional notes on others (early blight, Fusarium dry rot, wart, Fusarium wilt and common scab).

3. Ring rot and Bacterial wilt.

4. Golden nematode with occasional notes on others (Root Knot, Horsenettle Cyst and Osborne's Cyst).

5. Peach aphid, potato aphid, leaf hopper with occasional notes on others (flea beetle and Colorado beetle).

Frost Resistance

Potato varieties with foliage resistant to or tolerant of frost could be very useful in certain areas. Late spring frosts can have devastating effects on early crops and planting in many areas is normally delayed until frosts are not expected. Frosts may also terminate the growth of late-maturing varieties before tuber growth has ceased.

1. BUDYKINA, N.P., DROZDOV; S.N. and SINEL'NIKOVA, V.N. (1971). (Comparative frost resistance of wild potato species). Trudy po Prikladnoi Botanike, Genetike i Seleksti 46, 63-69.

2. DEARBORN, C.H. (1969). Alaska Frostless, an inherently frost resistant potato variety. American Potato Journal 46, 1-4.

3. FIRBAS, H. (1962). Zusammenhange zwischen Trockenheit und Frostresistenz. Zeitschrift für Pflanzenzuchtung, 48, 29-35.

4. FIRBAS, H. (1962). Reaktion von Wildkartoffelarten unterschiedlicker Frostresistenz auf Kalteeinflusse verschiedener Starke und Daner. Zeitschrift für Pflanzenzuchtung, 48, 101-105.

5. FIRBAS, H. and ROSS, H. (1961). Züchtung auf Frostresistenz bei der Kartoffel. I. Über die Frostresistenz des Laubes von Wildarten und Primitivformen der Kartoffel und ihre Beziehung zür Höhenlage des Artareals. Zeitschrift für Pflanzenzuchtung 45, 259-299.

6. FIRBAS, H. and ROSS, H. (1962). Zü chtung auf Frostresistenz bei der Kartoffel. II. Über die Frostresistenz der Knolle und ihre Beziehung zür Frostresistenz des Laubes. Zeitschrift für Pflanzenzuchtung, 47, 52-56.

7. HAWKES, J.G. (1962). The origin of Solanum juzepczukii Buk. and S. curtilobum Juz. et Buk. Zeitschrift für Pflanzenzuchtung 47, 1-14.

8. RICHARDSON, D.G. and ESTRADA RAMOS, N. (1971). Evaluation of frost resistant tuber-bearing Solanum hybrids. American Potato Journal 48, 339-343.

9. ROSS, R.W. and ROWE, P.R. (1965). Frost resistance among the Solanum species in the IR-1 potato collection. American Potato Journal, 42, 177-185.

10. ROSS, R.W. and ROWE, P.R. (1969). Utilizing the frost resistance of diploid Solanum species. American Potato Journal, 46, 5-13.

11. SUKUMARAN, N.P. and WEISER, C.J. (1970). A possible standard freezing test for evaluating tolerance in potato varieties. American Potato Journal, 47, 360 (Abstract)

Sources of resistance:

(a) Tuberosum potatoes - none

(b) Andigena potatoes - none? Ref. 5 suggests some.

(c) Cultivated triploids and pentaploids - resistance in *S. juzepczukii* and to a lesser extent in *S. curtilobum* - to be expected because these are hybrid "species" with *S. acaule* (see below) as a parent (Ref. 7).

(d) Cultivated diploids. Ref. 5 suggests some in some varieties of *S. ajanhuiri* and *S. goniocalyx*.

(e) Wild species - all authors agree that *S. acaule* has the hignest resistance (Ref. 1, 4 & 5). But resistance is also found in other species (Refs. 9 & 10) including many diploids such as *S. boliviense*, *S. canasense*, *S. chromatophilum*, *S. commersonii*, *S. megistacrolobum*, *S. multidissectum*, *S. raphanifolium*, *S. sanctae-rosae*, *S. sogarandinum*, *S. spegazinii* and *S. vernei*.

Tests:

Not easy to decide, short severe frost more damage than prolonged mild frost (Ref. 4); hardening of plants before test (Ref. 1); plants

receiving only sufficient water to prevent wilting were more resistant than plants grown under damp conditions (Ref. 3); possible test based on detached leaflets (Ref. 11); tuber resistance often associated with foliage resistance (Ref. 6). Inheritance - presumably due to polygenes and hybrids inherit at least some resistance (e.g. Ref. 8) and a variety with some frost resistance has been bred (Ref. 2).

Further work:

Probably not easy to use the S.acaule source of resistance and might be better to investigate diploid species sources. It would be interesting to have more information on how resistant are forms of the two cultivated species, *S. ajanhuiri* and *S. goniocalyx*.

It also needs to be decided on how frost resistance is inherited and the degree of resistance which it is likely can be achieved. Would this degree be adequate?

It may be worth noting that very little progress has been made in utilizing sources of frost resistance, e.g. Ref. 1, published in 1971, is still comparing wild species and confirming that *S. acaule* has the highest resistance without previous hardening.

Are there any areas where it would be possible to rely on having a frost every day, or nearly so, in order that laboratory tests could be compared with results in the field?

Drought Resistance

As is well known to every practical potato breeder who raises his stocks in a good seed district of high rainfall and tests his stocks in an area of relatively low rainfall, big differences occur in performance of clones in the two districts. Many clones which perform well in the high rainfall area are too short and low yielding in the drier area. Whether it would be possible to produce varieties with high tolerance of drought is, however, a much more difficult problem.

Only one recent reference on drought resistance was found:

RANA MUHMAMAD SALEEM and MUHAMMAD-SHAFI (1966). Drought resistance studies in different potato varieties and interspecific hybrids in West Pakistan. *West Pakistan Journal of Agricultural Research* 4, 99-120.

The authors claim that certain Tuberosum x Andigena and Tuberosum x S. commersonii hybrids showed better drought resistance than Tuberosum varieties. Drought resistance was also recorded by Ross and Rowe (IR-1 Potato Collection, see page 7) in lines of Tuberosum from Chile, in S. sparsipilum and S. gandarillaii. It presumably may exist in many wild species.

Further work:

The physiology of drought resistance in crop plants is a difficult subject - it is obviously no advantage to have a genotype which resists drought by closing its stomata to combat water loss and at the same time cannot get the carbon dioxide necessary to make dry matter. Active work is being done with other crops and it may be advisable to wait the results of this physiological work before investigating the problem with potatoes.

Heat Tolerance

Heat tolerance, as opposed to drought resistance, has been considered in the following three publications:

KHANNA, M.L. (1966). Breeding potato varieties tolerant to higher thermoperiods. Current Science 35, 143-144.

OCHOA, C. (1965). Antarqui, nueva variedad de papa precoz, tolerante al calor y auto-esteril. Anales Científicos (Lima) 3, 385-388.

SALEEM, R.M. and SHAFI, M. (1965). Heat resistance studies in different potato varieties and interspecific hybrids in West Pakistan. West Pakistan Journal of Agricultural Research 3, 85-102.

It appears that Andigena varieties may have more heat tolerance than Tuberosum varieties. The variety Antarqui, bred from a Andigenum x Tuberosum double cross was claimed to be tolerant of 18-24°C.

Further work:

It would appear that breeders interested in heat tolerance should investigate Andigena crosses.

Virus Resistance

The following types of virus resistance in potatoes are recognized: tolerance, infection resistance, hypersensitivity which often gives 'field immunity', and extreme resistance or immunity. To these four types of resistance can be added a fifth, vector resistance. This is resistance to the aphid or other vector and not to the virus itself.

Tolerance to virus infection is often considered to be of small importance in potatoes, or even undesirable because, with roguing not easy, stocks of tolerant varieties may act as a reservoir of the virus. Under certain conditions, however, tolerance may be valuable. For example, in the Isle of Jersey (Channel Isles), it is only the tolerance of the main variety, Jersey Royal (International Kidney), to virus Y that allows this variety to be grown year after year in an environment where aphid populations are high and where "seed" is not imported from a good seed growing district.

There are many viruses (including viroids and mycoplasmas) which can infect potatoes and not all of them occur in every country where potatoes are grown. There is evidence for several more potato viruses, or more strains of viruses, occurring in South America than in Europe, etc. - for example see the following references:

DIAZ MORENO, J. (1966). Incidencia del virus del amarillamiento de venas en papa en el Ecuador y su transmisión a través de los tubérculos. Turrialba 16, 15-24.

MONASTERIOS DE LA TORRE, T. (1966). Presence of viruses in Bolivian potatoes. Turrialba 16, 257-260.

McKEE, R.K. Virus infection in South American potatoes. European Potato Journal 7, 145-151.

Obviously great care should be taken with Potato Collections not to introduce new viruses, or a new strain of a virus already present, into the potato stocks of any country. Potato Collections do tend to be heavily infected with some viruses - see, for example,

ZADINA, M. (1970). (The distribution of virus M in a world collection of potatoes). Rostlinna Vyroba 16, 721-726 - of 630 stocks examined, only 146 were not infected with virus M, an uncommon virus in many parts of Europe. That a newly introduced strain of a virus can have serious effects was shown by the tobacco veinal necrosis strain of virus Y, see:

BRÜCHER, H. (1969). Observations on origin and expansion of Y^N virus in South America. Angewandte Botanik 43, 241-249.

To a large extent the amount of virus in a Potato Collection can be reduced by putting it into true seed as most viruses are not transmitted through true seed - there is, however, see below (Potato Spindle Tuber Virus) at least one important exception to this rule.

There is an extensive literature on potato viruses and it has been difficult to decide how to treat sources of resistance to them. As already emphasized for scientific work on potatoes generally, until recently most work on potato viruses has been done in the USA, Europe and other developed areas. This must have affected greatly ideas on the importance of the various viruses.

The way in which a virus is spread may be important in assessing its control and also its economic importance. The latter may also depend upon whether good "seed" districts exist and possibly also on whether reliable and quick serological tests are available to assist in the inspection and roguing of seed stocks.

Many sources of virus resistance are listed by Ross and Rowe (IR-1 Potato Collection). A recent publication:

COCKERHAM, G. (1970). Genetical studies on resistance to potato viruses X and Y. Heredity 25, 309-348, is very useful in showing how widespread both in cultivated and wild species are genes for resistance to virus X and to virus Y (including virus A) and that some of the genes in different species appear to be allelomorphic. German work on resistance to virus diseases has been extensive; summaries of the work can be found in:

ROSS, H. (1961). Die Züchtung auf Virusresistenz bei Pflanzen. Berichten der Deutschen Botanischen Gesellschaft 74, 23-35.

ROSS, H. (1966). The use of wild Solanum species in German potato breeding of the past and today. American Potato Journal 43, 63-80.

Potato Spindle Tuber Virus - this is a viroid (see DIENER, T.O. (1972). Viroids. Advances in Virus Research 17, 259-313) and is spread by many means, including leaf contact. It is also transmitted through true seed and possibly to some extent through pollen. Infected plants cannot be recognized by serological tests. Test plants for mild strains are not satisfactory (but see below).

Sources of resistance:

MANZER, F.E., AKELEY, R.V. and MERRIAM, D. (1964). Resistance in _Solanum tuberosum_ to mechanical inoculation with the potato spindle tuber virus. _American Potato Journal_, 41, 411-416.

BAGNALL, R.H. (1972). Resistance to potato viruses M, S, X and spindle tuber virus in tuber-bearing Solanum species. _American Potato Journal_ 49, 342-348.

The first reference claimed resistance very occasionally in Tuberosum progenies, the second in some forms of the wild species. _S. guerroense_, _S. hjertingii_ and _S. multidissectum_ (see also Ross & Rowe,1965)

Importance: mild strains probably depress yield by 10%; infection by severe strains produces much more damage.

Future work: not an easy virus to work with, especially as it is dangerous to have it near healthy potato stocks which can easily become infected. A good tester plant for mild strains would be useful for any work and also for testing accessions in collection. This may have been found in _Scopolia sinensis_ - see:

SINGH, R.P. (1973). Experimental host range of the potato spindle tuber 'virus'. _American Potato Journal_ 50, 111-123.

Potato Virus S - ubiquitous; spread by leaf contact; infected plants can be recognized by serological tests; reduction in yield not more than 5-10%.

Sources of Resistance:

Tuberosum potatoes - VULIC, M. and HUNNIUS, W. (1967). Zur "Immunität" der Sorte Saco gegenüber dem S-virus der Kartoffel. _Züchter_ 37, 243-245 - tests show the USA variety Saco to be highly resistant but not immune to S virus - also found by others.

Andigena potatoes - BAERECKE, M.L. (1967). Überempfindlichkeit gegen das S-Virus der Kartoffel in einen bolivianischen _andigena_ - Klon. _Züchter_ 37, 281-286 - gene Ns for hypersensitive type of resistance in the Andigena potato, clone PI 1258907.

Wild species - BAGNALL, R.H. (1972). Resistance to potato viruses M, S, X and spindle tuber virus in tuber bearing _Solanum_ species. _American Potato Journal_ 49, 342-348. - resistance was found in _S. gigantophyllum_ (may also be resistant to virus M), _S. boergii_, _S. caldasii_ and _S. emmae_.

Future work: If resistance to virus S is required, then the Andigena source (PI 1258907) may be adequate, particularly as it appears to be due to a single dominant gene. A search for similar genes in other Andigenas might be worthwhile. On the other hand virus S is not one of the most serious potato viruses and control can be achieved by serological testing of plants in seed stocks.

Potato Virus X - ubiquitous; spread by leaf contact; exists in many strains. Reduction in yield from mild strains may be not more than 5%, but, combined with another virus such as A, effect on yield may be large. Infected plants can be recognized by serological tests.

Sources of resistance: they have been summarized by Cockerham (Ref. on page 12).

Tuberosum potatoes: Nx and Nb genes give hypersensitive reactions resulting in field immunity to certain strains only.

Andigena potatoes: Rx in USDA 41956 (bred from an Andigena) and a similar gene in CPC 1673 (the main source of resistance used in breeding varieties resistant to pathotype of *Heterodera rostochiensis*) gives extreme resistance to all strains. This gene is in many new Dutch varieties. Another gene in Andigena controls hypersensitive reactions to all strains of virus X.

Wild species: genes controlling extreme resistance to all strains of virus X have been found in *S. chacoense* and *S. acaule*, also possibly in *S. microdontum*.

Future work: The CPC 1673, USDA 41956 and other Andigena sources should be sufficient for breeders. As with virus S, resistance to virus X is not at present given a high priority in many breeding programmes - possibly because of control by serological testing and only minor effects on yields. On the other hand varieties resistant to virus X are much easier to handle in producing certified seed than susceptible varieties.

Potato Virus Y (including Potato Virus A) - a non-persistent virus spread by aphids (therefore control by systematic insecticides not so efficient as for leaf roll); exists in many strains, e.g. tobacco veinal necrosis; potato virus A and C; and other more typical Y types may cause large reductions in yield.

Sources of Resistance: for genes giving extreme resistance see Cockerham (1970) - reference on page 12. Resistance to infection of a fairly high degree can be found and bred for, see for example:

LANA, E.P. and BENSON, A.P. (1967). Controlled testing and and breeding for field resistance to potato virus Y. American Potato Journal 44, 128-136. Tolerance of a high order to virus Y also occurs in some varieties.

Tuberosum potatoes - gene Na is present in many varieties and give field-immunity to virus A but not to the typical strains of virus (in some varieties it is closely linked to Nx). Infection resistance can also be found, e.g. in the British variety Pentland Crown, to typical virus Y strains. (There is also a gene Nc giving field immunity to virus C, an aberrant strain of Y, but this is not of any practical importance).

Andigena potatoes - Na and Nc genes occur but no genes giving extreme resistance to typical strains of Y.

Cultivated diploids - probably as Tuberosum and Andigena.

Wild species - very valuable as sources of extreme resistance to all strains of virus Y. They occur in:

S. chacoense

S. microdontum

S. demissum

S. hougasii

and *S. stoloniferum*

At least the *S. stoloniferum* genes have been transferred to Tuberosum clones of about commercial standard (Dr. T.M.W. Davidson at the Scottish Plant Breeding Station) and there must be further, probably unpublished, work on the utilization of these sources of resistance.

Future work: obviously should be on utilizing the sources of resistance in the above wild species. It would be advisable to check the resistance of material bred from such sources against a wide range of Y isolates and also to make sure that it functions efficiently in the field.

Leaf Roll Virus - transmitted by aphids; a persistent virus and some control can be achieved by systemic insecticides. Nearly always causes severe reductions in yield but some varieties fairly tolerant. Infection resistance also occurs.

References:

BAEREOKE, M.L. (1961). Erfahrungen mit einjahringen Kartoffelabauversuchen unter starken Blattroll-infectionsbedigungen. Zeitschrift für Pflanzenzüchtung 45, 225-253.

HAMANN, U., GALL, H. and MOLLE, K-H. (1968). Erfahrungen bei der Prufung von Kartoffelzuchtmaterial auf Blattrollvirus-resistenz in Laboratorium. Theoretical and Applied Genetics 38, 85-89.

MacKINNON, J.P. (1970). Comparative levels of leaf roll virus resistance in potato varieties and seedlings. American Potato Journal 47, 444-446

SIKKA, L.C. and MUNRO, J. (1968). Resistance to the potato leaf roll virus in certain Solanum tuberosum seedlings. Indian Phytopathology 21, 161-170.

All the above references refer to infection resistance in Tuberosum material. The only reference known to me on other possible types of resistance is in Ross (1966) in which it is said that Dr. Baerecke found in S. raphanifolium "a strong intolerance reaction to the leaf-roll virus".

Ross and Rowe (1969 - IRI Potato Collection) lists resistance as occurring in several accessions, mostly wild species. The data are presumably from unpublished reports.

Further work: Resistance to leaf roll appears to be a very difficult problem and a good source of resistance does not seem to be available. Using the present known type of resistance to infection, which appears to be controlled by polygenes, makes it very difficult to find clones with the many other qualities needed in a commercial variety. Resistance to leaf roll will presumably become more important when there are many varieties resistant to virus Y. A possible solution is to breed varieties resistant to the aphid vectors.

Other Viruses - in addition to the viruses already mentioned there are several others which are of local importance. They include:

Potato Mop-top virus (CALVERT, E.L. (1968). The reaction of potato varieties to potato mop-top virus. Records of Agricultural Research in Northern Ireland, 17, 31-40. An interesting virus in that the vector is the fungus Spongospora subterranea; was not noticed to be

important until viruses A, Y and Leaf Roll had been all but eliminated in seed stocks.

Tobacco Rattle Virus - transmitted by migratory nematodes; important in certain areas of western Europe as the main cause of spraing; References: RICHARDSON, D.E. (1970). The resistance of some potato varieties to spraing caused by tobacco rattle virus. Journal of the National Institute of Agricultural Botany 12, 112-118; SEPPANEN, E. (1972). The reaction to some potato varieties to spraing caused by tobacco rattle virus. Journal of the Scientific Agricultural Society of Finland, 44, 76-82. Apparently immune Tuberosum varieties are known, e.g. Bintje and Record; no published results but immunity may be due to a single dominant gene.

Resistance to Bacterial Diseases

There are three important bacterial diseases of potatoes: (*Erwinia phytophthora* Appel or *Erwinia caratovora* (Jones) Bergey et al. var *atroseptica* (van Hall) Dye), ring rot (*Corynebacterium sepedonicum* (Spiek. & Kotth.) Skapt. & Burkh.), and brown rot or bacterial wilt (*Pseudomonas solanacearum* E.F. Smith).

Blackleg - control of blackleg should be possible in the future by the stemcutting technique of producing seed stocks. Although there was work in the 1950s on screening wild species for resistance, this has now apparently ceased. Reaction to blackleg is not given in Ross and Rowe (1969 - IR - 1 Potato Collection). Two recent references have been found:

DOBIAS, K. (1970). (The resistance of varieties of a world collection of potatoes against blackleg (*E. carotovora* (Jones) Holland)). Rostlina Vyroba, 16, 687-692.

KOROMYSLOVA, M.I. (1972). (Initial material for breeding potatoes for resistance to blackleg). Byulleten' Vsesoyuznogo Ordena Lenina Institute Rastenievodsto Imeni N.I. Vavilova, N°22, pp. 35-38.

The authors claim resistance in *S.chacoense* and *S. setulosisylum*; the most resistant cultivars were in *S. phureja* and *S. rybinii*; but no form was immune.

Further work on resistance sources: at present not worth doing.

Ring rot. Resistance to ring rot has been claimed for some Tuberosum varieties and for wild species including *S. acaule*. It is resistance

rather than immunity. There appears to be no recent work - this is presumably because ring rot can be controlled by seed growers using good cultural practices.

Further work on resistance sources: at present not worth doing.

Brown rot or bacterial wilt - this is a serious disease where soil temperatures are high and there has been an interest in sources of resistance to Pseudomonas solanacearum. References:

(a) THURSTON, H.D. and LOZANO, T.J.C. (1968). Resistance to bacterial wilt of potatoes in Colombian clones of Solanum phureja. American Potato Journal 45, 51-55.

(b) SEQUEIRA, L. and ROWE, P.R. (1969). Selection and utilization of Solanum phureja clones with high resistance to different strains of Pseudomonas solanacearum. American Potato Journal 46, 451-462.

(c) ROWE, P.R. and SEQUEIRA, L. (1970). Inheritance of resistance to Pseudomonas solanacearum in Solanum phureja. Phytopathology 60, 1499-1501.

(d) FRENCH, E.R. (1973). Evaluación de la resistencia de clones de papa a Pseudomonas solanacearum. Phytopathology 62, 757-758 (Abstract)

(e) GONZALEZ, L.C. SEQUEIRA, L., ROWE, P.R. and BIANCHINI, R. (1973). Field resistance to bacterial wilt in hybrid potato progenies. Phytopathology 62, 760 (Abstract).

(f) ROWE, P.R., SEQUEIRA, L. and GONZALEZ, L.C. (1972). Additional genes for resistance to Pseudomonas solanacearum in Solanum phureja. Phytopathology 62, 1093-1094.

Although resistance has been claimed in occasional accessions of several species, recent work has been concentrated on using certain clones of the diploid, cultivated species, S. phureja. Resistance is apparently not common, e.g. 6 resistant in 1061 clones tested (ref. a). There are also races of the bacteria and potato clones may be resistant to all or only to one (ref. b). Resistance is due to a number of dominant genes plus modifiers (ref. c and f) and varies with soil temperature, varieties being more susceptible the higher the temperature (ref. d). It is possible to transfer the resistance to S. tuberosum progenies (ref. e) but the degree of resistance varies with the virulence of the bacterial race.

Further work: the obvious place to look for further resistance are any clones of *S. phureja* which have not been previously tested. Bacterial wilt is a serious disease in both India and Kenya; it might therefore be advisable to test resistant clones in both these countries. Obviously there is a big danger of the bacteria producing new races.

Resistance to Disease caused by Fungi (including Actinomycetes)

Many fungi can produce diseases of potatoes and it has only been possible to consider the apparently more important diseases. Relatively uncommon diseases can, however, be important in restricted areas or become important if a new variety with otherwise very good characters is very susceptible.

Common Scab (*Streptomyces scabies*) - widespread; spoils the appearance of tubers rather than reduces yield. Sources of resistance: common scab is one of the other fungi in Ross and Rowe (1969). Resistance has been claimed in a number of species, including *S. tuberosum* both ssp. *tuberosum* and ssp. *andigena*. There are several resistant Tuberosum varieties which can be used as a source of resistance; e.g. see:

WENZL, H. (1962). Beitrage zur okologie des Kartoffelschorfes (*Spongospora* and *Actinomyces* scab). *Pflanzenschutzberichte* 29, 33-64.

Resistance in Tuberosum varieties can be found in their dihaploids and is due to more than one gene:

CIPAR, M.S. and LAWRENCE, C.H. (1972). Scab resistance of haploids from two *Solanum tuberosum* cultivars. *American Potato Journal* 49, 117-119.

ALAM, Z. and PELOQUIN, S.J. (1971). Variation in scab reaction of 24-chromosome *S. tuberosum* clones and families. *American Potato Journal* 48, 301-302 (Abstract). A reference to resistance in potatoes other than Tuberosum is:

DIONNE, L.A. and LAWRENCE, C.H. (1961). Early scab resistant derivatives of *Solanum chacoense* x *Solanum phureja*. *American Potato Journal* 38, 6-8. It should also be noted that there are aberrant types of *Streptomyces* scab to which varieties resistant to common scab are not resistant: fortunately they are rare in occurrence:

HARRISON, M.D. (1962). Potato russet scab, its cause and factors affecting its development. American Potato Journal 39, 368-387.

Further work: probably adequate sources of resistance to common scab in Tuberosum and Andigena potatoes. Techniques for tests of resistance also probably adequate - the influence of soil moisture on scab development is now well understood.

Powdery Scab (Spongospora subterranea) - although not listed by Ross and Rowe (1969), powdery scab can be a serious disease in certain wet areas and five recent references were found to sources of resistance:

DUTT, B.L. and PUSKARNATH (1960). Resistance of potato varieties to powdery scab. Indian Potato Journal 2, 78082.

WENZL (1962) - see reference under common scab.

MANZER, F.E., AKELEY, R.V. and MERRIAM, D. (1964). Resistance to powdery scab in Solanum tuberosum L. American Potato Journal 41, 374-376.

ZADINA, J. (1965). (Problems of breeding potatoes for resistance to Spongospora subterranea (Wallr.) Johnson) Genetika a Slechteni 38, 71-78.

KORDZINSKI, J. (1970). (Results of four years of investigation on the susceptibility of Polish potato varieties to powdery scab). Builetyn Instytutu Ziemniaka 1970 (N°6), pp. 65-77.

Considerable resistance exists in Tuberosum varieties; there are reports previous to 1960 of resistance in other species.

Future work: probably not a disease of sufficient importance to warrant screening potato collections for resistance; breeders (e.g. myself) may have unpublished data on resistance; testing methods at present not adequate as depend on an infested soil and a wet season.

Wart (Synchytrium endobioticum)- the use of so-called wart immune varieties is often quoted as being one of the triumphs of plant breeding; certainly their use, coupled with legislative action, has reduced wart in many countries so much that it now presents a problem of little importance. There are no immune varieties, only varieties of very high resistance:

NOBLE, M. and GLYNNE, M.D. (1970). Wart disease of potatoes. FAO Plant Protection Bulletin 18, 125-135.

In certain restricted areas there are more than one race of wart and resistance to these is not so widespread as to the common race, e.g.

PROUDFOOT, K.G. (1971). Further observations on races of potato wart in Newfoundland. Potato Research 4, 232-233.

Sources of resistance: widespread in Tuberosum and Andigena potatoes; also known in cultivated diploids and wild species (other fungi no. 3 in ROSS and ROWE, 1969).

Further work: not an important disease in many countries; probably Andigena potatoes will supply resistance to the uncommon races.

Blight (Phytophthora infestans) - There must have been more work done on blight disease of potatoes than on all other diseases of potatoes put together. It is also, of course, one of the classical examples of the failure of simple dominant gene-controlled, hypersensitive type resistance to give lasting protection because of the rapidity with which new races of the pathogen arise. The failure has given rise to breeding for the polygenically controlled "field resistance" which is expected to be durable and also, to a lesser extent, to breeding for resistance of tubers to infection.

The following 14 references have been chosen, not for comprehensiveness but to illustrate certain points:

1) NIEDERHAUSER, J.S. and COBB, W.C. (1959). The late blight of potatoes. Scientific American 200, 100-112.

2) CERVANTES, J. (1965). Late blight-resistance of nine Mexican potato varieties in ten years of field trials. American Potato Journal 42, 258 (Abstract).

3) LAPWOOD, D.H. (1971). Observations on blight (Phytophthora infestans) and resistant potatoes at Toluca, Mexico. Annals of Applied Biology, 68, 41-53.

4) BLACK, W. (1970). The nature and inheritance of field resistance to late blight (Phytophthora infestans) in potatoes. American Potato Journal 47, 279-288.

5) UMAERUS, V. (1970). Studies on field resistance to Phytophthora infestans. 5. Mechanisms of resistance and applications to potato breeding. Zeitschrift fur Pflanzenzuchtung 63, 1-23.

6) YOUNG, R.J., DEAHL, K.L. and GALLEGLY, M.E. (1972). American Potato Journal: 49, 365 (Abstract).

7) THURSTON, H.D., HEIDRICK, L.E. and GUZMAN, N.J. (1962). Partial resistance to Phytophthora infestans (Mont) de Bary within the Colección Central Colombiana. American Potato Journal 39, 63-69.

8) SIMMONDS, N.W. and MALCOLMSON, J.F. (1967). Resistance to late blight in Andigena potatoes. European Potato Journal 10, 161-166.

9) ESTRADA RAMOS, N. and GUZMAN NARANJO, J. (1969). Herencia de la resistencia de campo al "tizón" (Phytophthora infestans (Mont.) de Bary) en variedades cultivadas de papa.(subspecies tuberosa y andigena. Revista del Instituto Colombiano Agropecuarias 4, 117-137.

10) DIONNE, L.A. and HODGSON, W.A. (1966). Advances in potato late blight resistance. Canadian Agriculture 2, 28-29.

11) GRAHAM, K.M. and DIONNE, L.A. (1961). Crossability relationships of certain diploid Mexican Solanum species. Canadian Journal of Genetics and Cytology 3, 121-127.

12) DIONNE, L.A. (1963). Studies on the use of Solanum acaule as a bridge between Solanum tuberosum and species in the series Bulbocastana, Cardiophylla and Pinnatisecta. Euphytica 12, 263-269.

13) GRAHAM, K. (1965). Experimental hybridization in certain diploid Mexican Solanum species. Euphytica 14, 113-119.

14) LANGTON, F.A. (1972). The development of a laboratory method of assessing varietal resistance of potato tubers to late blight (Phytophthora infestans) Potato Research 15, 290-301.

The breeding of varieties with field resistance to blight has benefited greatly from the work of Niederhauser and co-workers in the Toluca Valley (réf.1-3) - in addition to breeding varieties suitable for Mexico (ref. 2), it was possible for workers in other countries to send material for testing. Workers in other countries (e.g. refs. 4,5 and 6) have added to the techniques necessary for testing for field resistance.

Sources of resistance:

Tuberosum potatoes - there is some field resistance present but it is small compared with that obtainable from Mexican wild species (ref. 6).

Andigena potatoes - most clones are more susceptible than Tuberosum varieties and a major difficulty in using Andigena potatoes as sources of resistance to cyst nematodes (Heterodera spp) is their marked susceptibility to blight. However it is claimed (ref. 7, 8 and 9) that some Andigena clones have a field resistance to blight higher than that of many Tuberosum varieties.

Diploid cultivated potatoes - ref. 7 claims that some S. phureja accessions have a high field resistance - most, however, are very susceptible.

Wild potatoes - the best sources of field resistance appear to be the Mexican wild potatoes of which most use has been made of S. demissum and S. stoloniferum (these species, of course, also contain R genes). Attempts to use other wild species (S. pinnatisectum, S. cardiophyllum, S. bulbocastanum, for example) as sources of field resistance are more difficult to use (ref. 10-13) because of sterility barriers.

Future work: it can be argued that there are now sufficient sources of field resistance to blight available for use by breeders, and it would also seem that the wild Mexican source is better than Andigena, or S. phureja sources. The continuation of facilities such as Toluca valley for testing may be advisable. Another type of resistance of tubers to infection, has not been explored to any extent - one particular difficulty is a quick test, tests such as those of Langton (ref. 14) are not satisfactory. So far the indications are that field resistance is stable and not eroded by the fungus producing new races (ref. 1 & 6). If the field resistance was not stable, there would obviously be a more urgent need to find new sources of resistance.

Early Blight (Alternaria solani) - resistance to early blight is listed in Ross and Rowe (1969) as no. 1 in other Fungi. It is recorded for wild species such as S. charcoense, S. commersonii and S. tarijense. There appears to be little recent work, an exception being:

DOUGLAS, D.R. and PAVEK, J.J. (1972). The relationship of the susceptibility of different clones of potatoes to early blight foliage and tuber infection. American Potato Journal 49, 370 (Abstract).

Future work: it needs to be decided whether the disease is important enough to warrant much work on discovering sources of resistance. If it is, then there is a necessity for finding locations where testing can be carried out.

Tuber Rots (Gangrene; dry rot; charcoal rot).

In addition to tuber rots caused by bacteria, there are at least three fungi which can cause severe rotting of tubers. Their importance varies with country. Gangrene (*Phoma exigua* var. *foveata*) is a serious disease where potatoes are harvested under cold conditions. Dry rot (*Fusarium coeruleum*) can also be serious under temperate conditions. Charcoal rot (*Macrophomina phaseoli*) is of particular importance in India.

Gangrene is not a disease mentioned by Ross and Rowe (1969). There are differences in susceptibility, for example:

BANG, H. (1972). Mottaglighet fur Phoma-rota i svenskt potatismaterial. Vaxtskyddsnotiser, 36, 46-47.

No survey of S. American potatoes for resistance has been made. Tests for resistance have been worked out.

Fusarium Dry Rot is no. 2 of Other Fungi of Ross and Rowe (1969). Resistance has been claimed for some Andigena accessions. It is also known in some Tuberosum varieties, for example:

AYERS, G.W. (1972). Fusarium decay in potatoes Canada Agriculture 17, 38-39.

Charcoal rot is important in India, see:

PUSKARNATH (1961). Potato breeding and genetics in India. India Journal of Genetics 21, 77-86.

DEVENDRA SAHAI., DUTT, B.L. and PAHARIA, K.D. (1970). Reaction of some wild and cultivated potato varieties to charcoal rot. American Potato Journal 47, 427-429.

The latter authors found resistance in six clones of *S. chacoense*- some resistance is also found in *S. tuberosum*.

Further work: these three tuber diseases are only important in certain areas and it should therefore be left to the local potato breeding organizations to screen material for resistance.

Verticillium and Fusarium Wilts - Verticillium wilt is considered important enough by Ross and Rowe (1969) to be given a separate column in their lists. Fusarium wilt is no. 4 in Other Fungi.

Resistance to Verticillium wilt (usually *V. albo-atrum*) has been found in many clones of Andigena (especially those from Colombia), in some clones of *S. phureja* and in several wild species (especially *S. chacoense* and *S. tarijense*). It also exists in a few potatoes grown in India (2 resistant and 31 tolerant out of 145 clones tested):

PHADTARE, S.G. and PUSKARNATH (1969). Occurrence of Verticillium wilt of potato in Simla hills and reaction of some commercial potato varieties to the pathogen. Indian Phytopathology, 22, 419-422.

It has been suggested that Peruvian potatoes contain useful germplasm for resistance to Fusarium wilts:

SEMINARIO, B., FRENCH, E.R. and NIELSEN, L.W. (1970). Resistencia de tubērculos a las Fusaria que afectan papa en el Peru. American Potato Journal, 47, 118-123.

Further work: not immediately necessary to screen for more sources of resistance as present known sources probably not being used.

Other Fungi - there are still more fungi which can cause damage to potatoes. They include skin spot (*Oospora pustulans*), stem canker (*Corticium solani*), silver scurf (*Spondylocladium atrovirens*), pink rot (*Phytophthora erythroseptica*), watery wound rot (*Pythium ultimum*), stalk break (*Sclerotinia sclerotiorum*), black dot (*Colletotrichum atramentarium*), and violet root rot (*Helicobasidium purpureum*) in temperate regions and others such as rust (*Puccinia pitteriana*) in Colombia and *Sclerotium rolfsii* wilt in India and *Thecophora solani* in the Andean regions of South America.

Resistance to Aphids

Aphids can on occasions cause direct damage to potato plants, but the main importance of aphid resistance is usually considered to be control of the aphid-transmitted virus diseases. There are three big reviews of aphid resistance:

RADCLIFFE, E.B. and LAUER, F.I. (1968). Resistance to *Myzus persicae* (Sulzer), *Macrosiphum euphorbiae* (Thomas), and *Empoasca fabae* (Harris) in the wild tuber-bearing *Solanum* (Tourn.) L species. *Technical Bulletin of Minnesota Agricultural Experimental Station* no. 259.

RADCLIFFE, E.B. and LAUER, F.I. (1970). Further studies on resistance to green peach aphid and potato aphid in the wild tuber-bearing *Solanum* species. *Journal of Economic Entomology*, 63, 110-114.

RADCLIFFE, E.B. and LAUER, F.I. (1971). An appraisal of aphid resistant tuber-bearing *Solanum* germplasm. *Technical Bulletin, Agricultural Experiment Station, University of Minnesota* no. 286, 24 pp.

Some of the above findings are also given in Ross and Rowe (1969). Resistance to both aphids, the peach aphid (*Myzus persicae*) and the potato aphid (*Macrosiphum euphorbiae*), are primarily in certain Mexican wild potato species. Many of the resistant species are difficult to cross with cultivated potatoes. There is no resistance of even a low degree in cultivated potatoes. The resistance of wild species (*S. polyadenium*, *S. tarijense* and *S. berthaultii*) which have glandular hairs that trap aphids has been investigated:

GIBSON, R.W. (1971a). Glandular hairs providing resistance to aphids in certain wild potato species. *Annals of Applied Biology*, 68, 113-119.

GIBSON, R.W. (1971b). The resistance of three *Solanum* species to *Myzus persicae*, *Macrosiphum euphorbiae* and *Aulacorthum solani* (Aphididae: Homoptera). *Annals of Applied Biology*, 68, 245-251.

Further work: again not necessary until more attempts have been made to use resources already discovered.

Resistance to Other Insects

In addition to aphids Ross and Rowe (1969) list the reactions of accessions to leaf hoppers(*Empoasca* spp.)and among Other Insects to flea beetle (*Epitrix* spp) and Colorado Beetle (*Leptinotarsa decemlineata*).

Resistance to potato leafhoppers was considered by Radcliffe and Lauer (1968 - full reference in aphids section, (see above). They found some resistance in Tuberosum potatoes (there is also tolerance, e.g. in the USA var.Sequoia) and in a few Andigena clones,

but much higher resistance in several wild Mexican species (e.g. S. bulbocastanum, S. pinnatisectum and S. demissum). Resistance to leaf-hoppers has also been considered by:

SANDFORD, L.L. and SLEEMAN, J.P. (1969). Genetic variation in a population of tetraploid potatoes: response to the potato leaf-hopper and potato flea beetle. American Potato Journal 46, 436 (Abstract).

SANDFORD, L.L., CARLSON, D.V. and HIBBS, E.T. (1972). Genetic variation in a population of tetraploid potatoes: foliage resistance to oviposition of the potato leaf-hopper. American Potato Journal 49, 98-108.

It appears that selecting for resistance to leaf-hopper would tend to increase susceptibility to flea beetle and vice versa. Resistance to flea beetle (no. 1 in Other Insects of Ross and Rowe,1969) is found in many potato accessions including Andigena potatoes and many wild species (e.g. S. stoloniferum).

Before 1950 it was considered desirable to breed for resistance to Colorado Beetle, particularly in Germany and eastern Europe. Although there are some recent publications on resistance to Colorado Beetle, it is not given a high priority now because of successful control by insecticides:

SCHWARZE, P. (1963). Uber den Glykoalkaloidgehalt und die Zusammensetzung des Glykoalkaloidkomplezes in Nachkommen der Artkreuzung Solanum tuberosum x Solanum chacoense. Zuchter 33, 275-281.

BUKASOV, S. (1972). (Breeding potato varieties resistant to Colorado beetle). Kartofel i Ovoskchi 11, 6.

Several species have resistance to Colorado Beetle, the most important of which is probably S. chacoense. There is a danger of resistant plants owing their resistance to high contents of alkaloids.

Further work: it does not seem that insect resistance, with the possible exception of leaf-hopper resistance, warrants any further work at the present time.

Resistance to Cyst Nematodes

The nematodes which feed on potatoes were considered in detail at a CIP Planning Conference held in February 1974. The

writer of these notes has seen the programme of the meeting, but not any papers prepared for it nor any recommendations made. Potato nematode problems are discussed here briefly because they have implications as to how work on other pests and diseases should be carried out. Also it should be noted that resistance to cyst nematodes would be among the top priorities if British, Dutch and West German breeders were asked to indicate what was the most important genetic resources they are interested in.

The modern work on breeding potatoes resistant to cyst nematodes starts with the work of:

ELLENBY, C. (1954). Resistance to the potato root eelworm, Heterodera rostochiensis Wollenweber. Nature, London 170, 1016

Dr. Ellenby, who was a lecturer at Newcastle University, England, screened the Commonwealth Potato Collection for resistance to potato cyst nematode (the golden nematode of the USA) and found resistance in the wild species, Solanum vernei, and 5 clones of Andigena potatoes in some 1,000 accessions. It should be noted that Dr. Ellenby had no official connection with the CPC. His test for resistance was simple - potatoes were planted in a nematode-infested soil and their root-balls examined at an appropriate stage. Plants with many cysts were susceptible, plants with no, or few, cysts were resistant. This simple test, which could be applied to many hundreds of selections a year, if necessary, is still that used by practical breeders, and its simplicity must have contributed much to the success in Europe and the USA in breeding resistant varieties in a relatively short time.

The second factor leading to quick progress in breeding resistant varieties was that the source of resistance used was in Andigena potatoes (usually CPC 1673) and was due to a single dominant gene.

The third factor which made success relatively easy was that in much of Europe there is only a single pathotype of Heterodera rostochiensis present - the extreme example is in Sweden where of 600 populations tested only one was capable of producing many cysts on resistant potatoes bred from the Andigena source:

VIDEGARD, G. (1969). Nematodresistenta sorter - saneringseffekt och faran fur resistensbrytare. Potatis 1969, pp. 26-28.

The situation is presumably due to only a very small number of cysts being introduced into Europe from S. America, and it has been found that European resistant varieties are not resistant to

many S. American nematode populations:

MAYER de SCURRAH, M., MAI, W.F. and PLAISTED, R.L. (1973). More about the potato nematode, Heterodera rostochiensis Woll. in Peru. American Potato Journal 50, 58-61.

MAYER DE SCURRAH, M. (1972). Variability in Heterodera attacking the potato in Peru. In Prospects for the potato in the developing world. Ed. E.R. French. Lima: CIP pp. 172-180.

It is now known that there are in Europe apparently two species of cyst nematode, H. rostochiensis sensu stricto and H. pallida. There are also more than one pathotype of each species. The Ellenby Andigena resistant material (e.g. CPC 1673) is only resistant to pathotype A of Heterodera rostochiensis; hence attention had had to be given to other sources of resistance including S. vernei which was already known to be resistant:

1) ROSS, H. and HUIJSMAN, C.A. (1969). Uber die Resistanz von Solanum (Tuberarium) Arten gegen europaische Rassen der Kartoffelnematoden (Heterodera rostochiensis Woll.) Theoretical and Applied Genetics 39, 113-123.

2) DESHMUKH, M.G. and WEISCHER, B. (1970). Resistance of wild species of potato to populations of Heterodera rostochiensis Woll. from West Germany. Potato Research 13, 129-138.

3) BOUWMAN, L.A. and ROSS, H. (1972). Differentiation between Heterodera rostochiensis and an undescribed allied species by female colour, morphometrics and pathogenicity. Nematologica 18, 265-269.

4) HUIJSMAN, C.A. (1972). Wilde en primitieve Solanum - soorten en aardappelmoeheids-resistentie. Zadbelangen 26, 228-229.

5) PLAISTED, R.L., SCURRAH, M.M. de and HARRISON, M.L. (1972). Resistance to the potato nematode Heterodera rostochiensis Woll. in clones derived from Solanum vernei. American Potato Journal 49, 364 (Abstract).

6) HOWARD, H.W., COLE, C.S. and FULLER, J.M. (1970). Further sources of resistance to Heterodera rostochiensis Woll. in the Andigena potatoes. Euphytica 19, 210-216.

7) ROTHACKER, D. and STELTER, H. (1971). Solanum tuberosum ssp. andigenum als Resistenzquelle fur die Nematodenresistenzzuchtung. See Plant Breeding Abstracts 42, Abstract 5481.

8) HUIJSMAN, C.A., KLINKENBERG, C.H. and OUDEN, H. den (1969). Tolerance to *Heterodera rostochiensis* Woll. among potato varieties and its relation to certain characteristics of root anatomy. *European Potato Journal* 12, 134-147.

The above 8 references are not comprehensive but have been chosen to illustrate certain aspects. Sources of resistance to *Heterodera pallida* and *H. rostochiensis*:

Tuberosum potatoes	-	Chile EBS 2084 (ref.1 only).
Andigena potatoes	-	CPC 2775, 2802 & 2805 (ref. 6 only).
Cultivated diploids	-	none

Wild species - *S. andreanum* (ref. 1); *S. boliviense* (ref. 2); *S. brevicacille* (ref. 2); *S. kurtzianum* (ref. 3); *S. leptophyses* (ref. 4); *S. megistacrolobum* (ref. 1 & 2); *S. multidissectum* (refs. 4 & 6); *S. oplocense* (refs. 1, 3 & 4); *S. sparsipilum* (refs. 1, 2 & 4); and *S. vernei* (refs. 1, 2, 3, 4 & 5). There may also be resistance in *S. acaule* and *S. chacoense* (ref. 4).

The most widely investigated of the sources of resistance to *H. pallida* and *H. rostochiensis* (all, not only A, pathotypes) is *S. vernei*. It is interesting to note that its resistance was thought to be non-race specific and to be caused by polygenes; more recent work (ref. 4) suggests it may be due to a series of major genes which are to some extent at least race-specific. *S. vernei* may even contain a major gene similar to that found in Andigena CPC 1673 (ref. 5). It has been suggested that various wild species are the best source of resistance e.g. *S. sparsipilum* or *S. oplocense*.

The Andigena resistance (ref. 6) was found in 5 lines which traces back to 3 accessions only in screening 310 self or sib-crosses and 370 crosses between clones. The resistance was thus rare - compare Ellenby's result but contrast with ref. 7 in which no fewer than 68 forms of Andigena were found to be resistant to pathotype A of *H. rostochiensis* - the latter may be a false result due to testing a short day species under long days (see also page 6).

It is possible that no source will be found with resistance to all pathotypes of all cyst nematode species; this would apply specially to S. America. In such circumstances tolerance to nematode attack could be valuable. Tolerance may exist (ref. 8).

Further work: work in progress may show that sources of resistance adequate to cover pathotypes of cyst nematodes present in Europe

already exist; the problem in S. America is more complex and needs further investigations which are being carried out. Nematode resistance is important as an indirect method of increasing potato yields.

Resistance to Other Nematodes

Resistance to root-knot nematodes, *Meloidogyne* species may be important in warmer soils. *Meloidogyne* species are Other Nematodes No. 1 in Ross and Rowe (1969). Reactions to *Meloidogyne* have been investigated by:

BRUCHER, H. (1967). Root knot-eelworm resistance in some South American tuber-forming Solanum species. *American Potato Journal* 44, 370-375.

NIRULA , K.K., NAYAR, N.M., BASSI, K.K. and SINGH, G. (1967). Reaction of tuber-bearing Solanum species to root knot nematode, *Meloidogyne incognita*. *American Potato Journal* 44, 66-69.

NIRULA, K.K., KHUSHU, C.L. and RAJ, B.T. (1969). Resistance in tuber-bearing *Solanum* species to root knot nematode, *Meloidogyne incognita*. *American Potato Journal* 46, 251-253.

Resistance to *M. incognita* and other species is found in many species, but no work on the inheritance of resistance appears to have been published.

Potatoes are also attacked by a race of the stem nematode (*Ditylenchus dispaci*) and resistance has been claimed:

GERMAN, E. (1972). (Resistance of potatoes to the stem nematode). *Kartofell i Ovoshchi*, no. 40 p.40.

There are also many migratory nematodes attacking potato roots. It is unlikely from comparison with work on other crop plants, that any resistance to these occurs.

Further work: there may be a case for more studies of resistance to *Meloidogyne*.

Yield. Although in potatoes breeding for disease resistance is often the easiest way of increasing yields, it may be possible by using in breeding programmes new sources of genetic variation to find hybrid vigour and to increase yields.

The cultivated diploid potatoes and many of the wild S. American diploid species are outbreeders with a well developed S allele system. Also, although the cultivated tetraploids are self-compatible, studies of their dihaploids has shown that they possess S alleles similar to those in the cultivated diploids. It may be that self-compatibility in Andigena and Tuberosum potatoes is due to competitive interaction of S alleles (i.e. S_1 S_2 pollen can function in S_1 S_1 S_2 S_2 styles). The Andigena and Tuberosum potatoes may therefore behave as outbreeders and not self-pollinators, particularly so far as vigour of offspring is concerned.

There is some evidence for hybrid vigour in tetraploid potatoes:

1) ROTHACKER, D. (1962). Populationsanalytische Untersuchungen uber die Leistung verschiedener Kreuzungskombinationen zwischen ssp. andigena und ssp. tuberosum von S. tuberosum. European Potato Journal 5, 1-13.

2) GLENDINNING, D.R. (1969). The performance of progenies obtained by crossing groups Andigena and Tuberosum of Solanum tuberosum. European Potato Journal 12, 13-19.

3) HANNEMAN, R.E. and PELOQUIN, S.J. (1969). Use of Phureja and haploids to enhance the yield of cultivated tetraploid potatoes. American Potato Journal 46, 436 (Abstract).

4) MENDIBURU, A. and PELOQUIN, S.J. (1971). High yielding tetraploids from 4x - 2x and 2x - 2x matings. American Potato Journal 48, 300-301.

Care is needed, however, in measuring hybrid vigour in potatoes, in particular it is necessary to compare clones of similar maturity.

Further work: because the Tuberosum varieties now used by breeders tend to be hybrid derivatives involving a wider range of parents than the Tuberosum varieties bred before 1940, it is possible that newer introductions may have some hybrid vigour. For S. America it might be interesting to study crosses between Andigenas from the different ends of its range.

Discussion

This survey of genetic resources, which is not completely comprehensive, suggests four major conclusions:

1. There is in the tuber-bearing Solanum species a vast store of germ plasm in both the cultivated and wild species.

2. There is a wide range of diseases and pests of varying importance.

3. Resistance to some diseases and pests may be found in either the cultivated tetraploids or the cultivated diploids but for certain pathogens resistance is only found in the wild species.

4. Even when resistance has been found, it is not being used to any extent in breeding programmes.

CONSERVATION OF GENETIC RESOURCES

Introduction

There are already in existence large collections of both cultivated and wild potatoes, and plans have been made (CIP Workshop on Germ-Plasm Exploration and Taxonomy of Potatoes, January 1973, Lima) to assemble even more material by a number of collecting expeditions between 1973 and 1977. The Workshop also suggested that the first priority should be the collection of cultivated forms and that the first priority in taxonomic research should be given to cultivated forms. The last four recommendations of the ten they made were:

"7. In relation to conservation work the workshop stressed that if the plans outlined in this paper come to fruition that adequate facilities be made for the expanded amount of material which the gene bank will have to hold.

8. Further, it was stressed that the bank should possess as broad a base as possible of material in the form of true seed. Research on the techniques to be used to convert the cultivated forms to true seed should be conducted as soon as possible.

9. In addition it was recognized that a limited number of cultivars, breeding lines and genetic stocks should be maintained clonally for a number of years, for demonstration and research purposes. Certain odd-number polyploids may also need to be maintained clonally.

10. Finally the workshop suggested, although conceding that this was beyond its brief, that there was an urgent need to increase efforts in evaluation to facilitate the utilization of the material for the needs of developing countries".

In my opinion these four recommendations will be very difficult to carry out and they need careful consideration. Considering the first three recommendations, it can be added that the CIP has about 4000 cultivated forms and expects to receive another 2000 to 4000 forms (P.R. Rowe in a letter discussing this workshop). I suggest:

1. That as much as possible of the material should be put immediately into true seed for at least three reasons:

(a) Maintaining material clonally is a time - and labour-consuming activity which is of little interest to those who do it.

(b) In spite of precautions, clones very quickly pick up virus diseases and the process tends to accelerate the longer the material is kept as clones.

(c) It is easier to distribute material as true seed and true seed causes very much less trouble from quarantine restrictions than to tubers.

2. It is too late to do the research on techniques to convert the cultivated forms to true seed. Fortunately the few techniques needed are already known and it should not be difficult to get most of the material into seed. Material that cannot be converted into true seed should be discarded - this may be contrary to what some conservationists would do, but it is not worth the time to keep such types when there is an abundance of more amenable material.

3. Evaluating the material cannot be organized very quickly and it needs experts to do it. Hence the material will have to be kept for many years before it can be evaluated.

Storage of True Seed

Once converted into true seed, material can be kept with very little trouble for many years. It appears to be a general rule for most species:

HARRINGTON, J.F. (1970). Seed and pollen storage for conservation of plant gene resources. In O.H. Frankel and E. Bennet (Editors). Genetic Resources in Plants: their Exploration and Conservation. Oxford: Blackwell Scientific Publications, pp. 501-521.

that the life of seeds is doubled for every 5° C drop in temperature. Potatoes are probably no exception to this rule and, although

SIMMONDS, N.W. (1968). Prolonged storage of potato seeds. European Potato Journal 11, 150-156.

suggests a limit of 12 years for low-dormant diploids and 16 years for deeply dormant tetraploids, the limits may be much longer using storage at 5° C (a temperature readily available in low cost refrigerators). Two other references:

ROSS, R.W. (1969). Seed dormancy and longevity in Solanum species. American Potato Journal 46, 438 (Abstract).

HOWARD, H.W. (1969). The storage of true seeds of potatoes. European Potato Journal 12, 278-279.
both suggest 15 years as a minimum for storage and that 20 years or even more may be possible (the Howard experiment reaches 20 years in 1974). Seeing that seed stored at room temperature (about 15°C) can be viable for at least 10 years, storage at 5°C may enable seed to be kept for 40 years. Even with a limit of 15 years, the advantages of keeping a collection as true seed are obvious.

The mechanics of keeping the collection as true seed requires a little consideration. It is of some advantage not to keep the seeds as big bulks but to divide them into 10 or so small bulks. When a distribution has to take place, it causes less disturbance to take one of the small packages out of store than to have to take a big bulk out, separate out a part of it for distribution, and then return the bulk to the cold store.

Pollen Storage

Pollen can be stored for two years at -20°C (deep freeze conditions) and such stored pollen can be very useful for pollinating pollen-sterile clones, particularly as it obviates having the pollen-fertile clone in flower at the same time as the pollen-sterile:

KING, J.R. (1955). Irish potato pollen storage. American Potato Journal 32, 386-391.

HOWARD, H.W. (1958). The storage of potato pollen. American Potato Journal 35, 676-678.

Induction of Flowering

Clones which do not flower can often be made to flower by either grafting scions on to tomato stocks or by "growing on a brick":

THINJN, G.A. (1954). Observations on flower induction with potatoes. Euphytica 3, 28-34.

Cultivated Tetraploids - Tuberosum potatoes

Many clones are pollen-sterile and the only way of keeping them as true seed must involve making crosses with pollen-fertile clones. Doing this, however, results in valuable characters due to polygenes being lost. A few varieties are also more or less ovule-sterile. It is, however, no real loss to lose such types as they are of little use in breeding programmes because of their sterility.

The Argentine tetraploid potatoes have not been studied to any extent and they may pose more problems in getting them into true seed than do the tetrapolid cultivated Andigena potatoes.

Cultivated Tetraploids - Andigena potatoes

The preservation of the germ plasm present in the Andigena potatoes is a major problem for the CIP. On the whole there is no lack of pollen-fertile clones but not every clone is pollen fertile. For example, of the 218 Andigena accessions received by the IR-1 Potato Collection as tubers, only 29 were available as clones, 16 as open-pollinated seed, 74 as selfed seed and 99 as hybrid seeds in 1969.

On the whole selfed seed is to be preferred to hybrid seed. If a desirable character is due to a single dominant gene, then there is little advantage for selfed over hybrid seed. On the other hand if the desirable character is due to a number of polygenes, selfed seed has a big advantage over hybrids for finding the desirable character again in the progeny.

Where selfed seed cannot be obtained and resource has to be made to producing hybrid seed, then it would presumably be advantageous to use as pollinators another clone from the same region. When it is necessary to screen an Andigena collection which has been put into true seed, it is useful to have progenies from selfed seed of the pollinators to compare with the progenies from crosses.

A further problem which will have to be considered in the future is what to do when the primary seed is reaching the end of its viability. The only process possible is sib-crossing for accessions preserved either as selfed or hybrid seed. How many sibs should be included in producing the new seed stock has never been considered. Space, time and labour will however set a limit to the number.

As suggested earlier, accessions from which seed cannot be obtained should be discarded. They are of no use to the potato breeder and, if preserved as clones, will in the end be a dangerous source of virus diseases.

Cultivated Triploids and Pentaploids

There seems to me to be no reason to conserve the few pentaploid *S. curtilobum* clones. It can be argued that these clones are unlikely to contain valuable genes not found in the cultivated tetraploids and diploids and the wild species, *S. acaule*.

The two triploid "species", *S. chaucha* and *S. juzepczukii*, can be treated with colchine to produce hexaploids which may be fertile:

HOWARD, H.W. (1961). The production of hexaploid *Solanum x juzepczukii*. *Euphytica*, 10, 95-100.

It would, however, be a difficult task to convert many triploids to hexaploids, and, as with the pentaploids, there are probably few, if any, valuable genes in the triploids which cannot also be found in the cultivated tetraploid and diploid potatoes and *S. acaule*.

The one feature which the triploid and pentaploid cultivated "species" may have is either resistance to or tolerance of virus diseases. If they are tolerant, this increases the danger of preserving them as clones from which the rest of a collection can become infected.

Cultivated Diploid Species

The cultivated diploid potatoes are self-incompatible and hence must normally be conserved as hybrid seed. Some can be selfed, either by bud-pollination or at the end of the season. But, as vigour is often lost on inbreeding, there is no doubt that they should be preserved as hybrid seed. Again the hybrid seed should be produced between clones from the same region.

Wild Species

These obviously should be conserved as seed.

SCREENING FOR VALUABLE GENES

There are two main problems to consider when considering the problem of screening for valuable genes. These are first what genes are wanted and secondly where is the screening to be done.

The purpose of the major part of these notes - Survey of Genetic Resources - was to consider which genes are wanted, which genes have already been found, and what are the problems in utilizing these genes in practical breeding programmes. One important conclusion was that it would be advisable to draw up an order of importance for screening for characters wanted in new varieties in the very many countries where potatoes are an important crop and in countries where they may become more important.

It seems obvious to me that it is unlikely that any single organization can do all the screening that is wanted. It was also pointed out earlier that for some diseases and pests there exist fewer pathotypes in many countries than in South America and hence that screening in South America might be much more severe than in the rest of the world. It would therefore be often advisable that the screening should be done in close contact with the breeders in any countries or even by the breeders themselves.

On the other hand it is obviously wasteful of effort for screening to be going on in very many places and it would often be impractical because of a lack of enough specialized pathologists have been trained to consider resistance to pathogens in a way of value to plant breeders and they do not always appreciate the difficulties of breeding new varieties. Neither do they realize that a moderate degree of resistance which it may be possible to breed for relatively easily must be the answer to a problem at present rather than a very high degree of resistance or immunity which it may be very difficult for breeders to incorporate in new varieties. There is a much better chance of useful screening being done if the pathologists are in close contact with the breeders.

It is not obvious to me how a co-operative scheme of screening potato collections should be organized but it is on the other hand obvious that it should be the task of the CIP to consider the problem. An interim measure could be for the CIP to

produce a "Potato Newsletter". The first issues of this would contain a request for countries to outline what they considered were the most important characters required in new varieties; whether they had adequate sources from which to obtain these characters, and, if not, were they screening for them; and what facilities they had or intended to provide for such screening. Later it should be possible to publish lists of new stocks with valuable characters which were available in different countries.

Finally it must be admitted that putting a collection into true seed can make screening for valuable genes more difficult. Consider, for example, a required character which is controlled by a single dominant gene. If selfed seed has to be screened, then three in four of the progeny will on average have the desired character; if hybrid seed has to be screened, then it is only one plant in two. This necessitates growing about five plants per progeny. The screening may also take a year longer as it often cannot be done satisfactorily with seedlings and needs plants grown from tubers.

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APPENDIX 2.

PROPOSED SCHEME FOR POTATO PRODUCTION FROM BOTANICAL SEED

The proposal is based on the use of sexual production of tetraploids via Zn gametes produced by first meiotic division restitution (FDR) in diploid clones (4X or 2X x 2X crosses).

Advantages

- Reasonably high level of uniformity by generating a homogeneously heterozygous population.
- Control of virus diseases even in the absence of a sophisticated certification seed program.
- Utilization of heterosis by mating optimally diverse hybrid clones in the production of seed.

Method

- Identify diploid clones that combine good agronomic characteristics with production of 2n gametes by FDR.
- Identify good combinations, i.e., clones that produce agronomically acceptable, mainly tetraploid, progeny efficiently. These means that

  1. they "nick" well
  2. produce 2n gametes in reasonably high numbers

If a female diploid parent with the required characters is not available, a male sterile tetraploid clone could be used as female in a 4X x 2X cross.

Procedure

Establish a crossing plot by planting the parents in the field. For example, 3 rows of the female 4X parent to one of the male parent.

The crossing plot should be isolated from other potato pollen sources.

Harvest fruits (only produced by the female parent).

The use of two diploid clones would be advisable if

1) 2n gametes are produced by FDR in both sexes (harvest of fruits from both parents).

2) The parents are self-incompatible.

3) The proportion of 4X progeny is high and

4) The 2X progeny is easily identify and discarded.